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Tech Notes

JANUARY 1991

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Technology fact sheets from Federal laboratories

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Center for the Utilization of Federal Technology

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Tech Notes

Highlighting Selected U.S. Government Technology & Resources

January 1991

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Published monthly by the National Technical Information Service (NTIS), Tech Notes bring together individual one- to two-page fact sheets prepared by Federal agencies, their laboratories, or contractors. These fact sheets highlight current Federal technology determined to have commercial or practical application. Topics cover new processes, materials, techniques, software, instrumentation, and resources.

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Below are two representative examples of how each Tech Note fact sheet provides you with a source of further information. In most cases, this information is provided directly by the agency or its laboratory. However, there are cases where NTIS is the source for backup documentation. In these cases, use the order form at the end.

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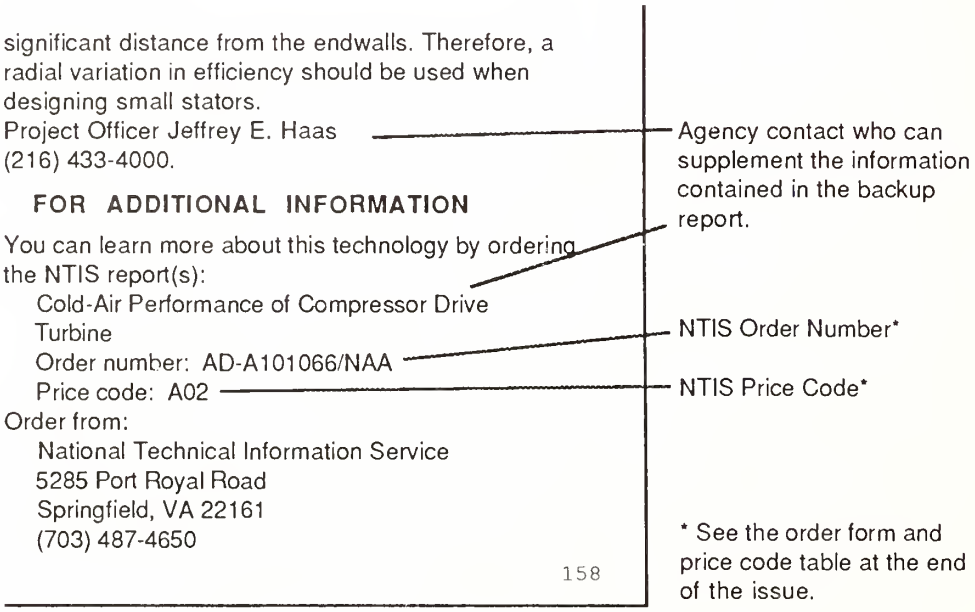
significant distance from the endwalls. Therefore, a radial variation in efficiency should be used when designing small stators.
Project Officer Jeffrey E. Haas
(216) 433-4000.
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You can learn more about this technology by ordering the NTIS report(s):
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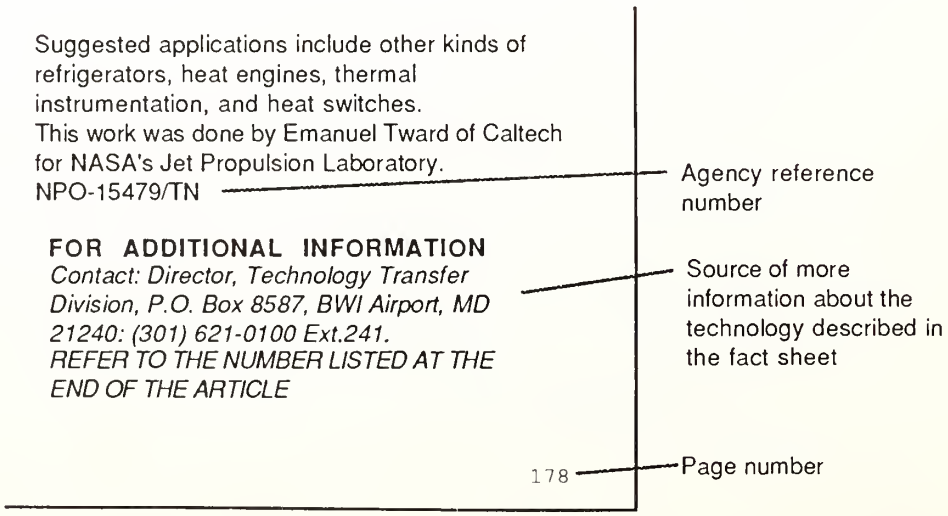
Suggested applications include other kinds of refrigerators, heat engines, thermal instrumentation, and heat switches.
This work was done by Emanuel Tward of Caltech for NASA's Jet Propulsion Laboratory.
NPO-15479/TN
FOR ADDITIONAL INFORMATION
Contact: Director, Technology Transfer Division, P.O. Box 8587, BWI Airport, MD 21240: (301) 621-0100 Ext.241.
REFER TO THE NUMBER LISTED AT THE END OF THE ARTICLE
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0003 Spotting Swine Dysentery

0004 Tanks for Saving Water

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0005 Program Manipulates Plots for Effective Display—Plots can be displayed in a variety of useful ways.

0006 Risk Assessment the DOE Way

0007 Balancing Loads Among Parallel Data Processors—A heuristic algorithm minimizes the amount of memory used by a multiprocessor system. (Licensing Opportunity)

0008 Bus-Programmable Slave Card—A specialized microprocessor development system is not necessary. (Licensing Opportunity)

0009 Truncation of Images for Correlation—Correlation could be performed on a relatively small computer. (Licensing Opportunity)

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0028 Starting Circuit for Erasable Programmable Logic Device—The voltage regulator is bypassed to supply the starting current.

0064 Checking Automated-Welder Programs by Computer—A personal-computer-based system, distinct from the welding-control computer, finds software errors.

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0011 Fiber Optic Connectors

0012 Electromagnetic Properties of Superconductors

0013 Metallized Synthetic Cable Developed

0014 Navy Reviews Teletouch Display Development

0015 Simple Monopole Inductively Loaded Antenna System Developed

0016 Active Limiters for Photodetectors—Intense radiation would trigger protective electro-optical shutters.

0017 Dielectric-Filled Paraboloidal Front Ends—Planar antennas with receiving and/or transmitting circuits are integrated at the focal point.

0018 Calculating Performances of Fabry-Perot Etalons—Effects of changes in design can be determined quickly.

0019 Directional Couplers for Detecting Circular Waveguide Modes—Samples of TE(11) and TE(12) modes are coupled selectively out of a circular waveguide.

0020 Effects of Dose Rates on Radiation Damage in CMOS Parts—Damage is more severe at lower dose rates.

0021 High-Efficiency Klystron for Television Transmitters—A multistage depressed collector recycles energy from spent electrons.

0022 MCT/MOSFET Switch—A hybrid of two different switching transistors has large safe operating area and high speed. (Licensing Opportunity)

0023 Millimeter-Wave Quantum-Well Frequency Multipliers—A double-barrier quantum-well GaAs diode produced 0.25 mW output at the third harmonic, 191 GHz. (Licensing Opportunity)

0024 More About Lens Antenna for Mobile/Satellite Communication—Details of a flat phased-array design are presented.

0025 Phase Calibration of Radar Polarimetric Data—Calibration parameters are extracted from the data themselves.

0026 Planar Microstrip Yagi Antennas—Mutual coupling between microstrip elements, ordinarily considered a nuisance, is used to advantage. (Licensing Opportunity)

0027 Real-Time Digital Compression of Television Image Data—Broadcast-quality images can be transmitted at low data rates. (Licensing Opportunity)

0028 Starting Circuit for Erasable Programmable Logic Device—The voltage regulator is bypassed to supply the starting current.

0029 Self-Aligned Guard Rings for Schottky-Barrier Diodes—The active area would be increased. (Licensing Opportunity)

0030 Switching Matrix for Optical Signals—Size, weight, and power consumption would be reduced. (Licensing Opportunity)

Testing & Instrumentation

0031 Diffraction Analysis of Distorted Reflector Antennas—The effects of systematic distortions of surfaces on radiation patterns are predicted.

0032 Computing Scattering Matrices for Circular Waveguides—This program computes scattering at junctions between sections on a common axis.

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0037 Copper Chloride Cathode for Liquid-Sodium Cell—Energy density is higher than that of previous liquid-sodium cells. (Licensing Opportunity)

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0053 Shaft-Rotation Detector—Rotation is deduced from a subtle component of vibration. (Licensing Opportunity)

0101 Compensating for Doppler Shift in Laser Instrumentation—The frequency of a tunable diode laser is adjusted to oppose the shift. (Licensing Opportunity)

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0033 Advanced Combustion System for Industrial Boilers

0034 Fireflies Light the Way to Improve Oil Yields

0035 Solid Oxide Fuel Cell/Hybrids for Transportation

0036 Energy-Efficient Windows and Window Coverings

0037 Copper Chloride Cathode for Liquid-Sodium Cell—Energy density is higher than that of previous liquid-sodium cells. (Licensing Opportunity)

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0038 FLAP Structural Dynamics Code

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0039 Adapter for 700 Series Flo-Lok Coupling for Single-Point Attachment Operation (Licensing Opportunity)

0040 Catalysts Improve Industrial Processes (Licensing Opportunity)

0041 Method of Recovering Adsorbed Liquid Compounds From Molecular Sieve Columns (Licensing Opportunity)

0042 Microbubble Flotation Development Unit

0043 Remote Sample Bottle Opener (Licensing Opportunity)

0044 Analysis of Stepped Labyrinth Seals—Rotodynamic coefficients are derived for compressible flow.

0045 Estimability and Regulability of Linear Systems—These properties provide criteria for reductions of errors and cost functions in control systems.

0046 Flow-Control Unit for Nitrogen and Hydrogen Gases—a replaceable unit connects to a single manifold plate for ease of service. (Licensing Opportunity)

0047 Piezoelectric Pushers Suppress Vibrations—Actuators are small, lightweight, and rugged.

0048 Helmet-Mounted Visual Display for Flight Simulation—Optical fibers transmit wide-angle images in response to motions of the head. (Licensing Opportunity)

0049 Reducing Aerodynamic Drag of Bluff Bodies—The simple addition of two panels eliminates as much as 80 percent of drag. (Licensing Opportunity)

Testing & Instrumentation

0050 Solid/Liquid Flow Measurement Using Refractive Index Matching

0051 Measuring Flow in the Space Shuttle

0052 Pressure-Measuring Diaphragm Transmits Optical Signals—A sapphire diaphragm would reduce the required number of instrumentation ports. (Licensing Opportunity)

0053 Shaft-Rotation Detector—Rotation is deduced from a subtle component of vibration. (Licensing Opportunity)

0054 Ultrasonic Monitor to Determine Crack-Opening Load—Harmonics of acoustical signals are generated by cracks.

0055 Vacuum-Guage Connection for Shipping Container—An external connector enables measurement of the vacuum in a stored part.

Other Items of Interest

0033 Advanced Combustion System for Industrial Boilers

0036 Energy-Efficient Windows and Window Coverings

0083 Holographic Reticle—This device could be used for noncontacting, nondestructive inspection of surfaces.

0105 Measurement of Water Sprays Generated by Airplane Tires—Water sprays produced by tires on wet runways are simulated and analyzed.

0106 Predicting Unsteady Aeroelastic Behavior—The equations for the motion of the wing and the flow field are solved iteratively and simultaneously.

Environmental Science & Technology

0056 Available Models for Estimating Emissions Resulting from Bioremediation: A Review

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0057 Evaluation of an Anion Exchange Resin for Sampling Ambient Level Phenolic Compounds

0058 Laboratory Method to Estimate Hydrogen Chloride Emission Potential Before Incineration of a Waste

0059 Materials Can Help Evaluate Industrial Atmosphere

Other Items of Interest

0060 Bellows-Sealed 1/4-Turn Ball Valves (Licensing Opportunity)

0066 Damping Seals and Bearings for a Turbomachine—Bearing loads are reduced to prolong service lives. (Licensing Opportunity)

0073 Polyphosphazene Semipermeable Membranes (Licensing Opportunity)

0095 Method for the Recovery of Silver from Silver Zeolite (Licensing Opportunity)

0098 Analyzing Environmental Pollutants (Licensing Opportunity)

0100 High-Temperature Quantitative Dilution Device for Oxides of Nitrogen Measurements via Chemiluminescent Monitors (Licensing Opportunity)

Manufacturing, Machinery & Tools

0060 Bellows-Sealed 1/4-Turn Ball Valves (Licensing Opportunity)

0061 Method for Controlling Gas Metal Arc Welding (Licensing Opportunity)

0062 Product Data Exchange Specification (PDES) Organization

0063 Advances in Research on Powder Metal Manufacturing

0064 Checking Automated-Welder Programs by Computer—A personal-computer-based system, distinct from the welding-control computer, finds software errors

0065 Controlled-Pinch Spot Welder—Compressed air furnishes repeatable clamping force.

0066 Damping Seals and Bearings for a Turbomachine—Bearing loads are reduced to prolong service lives. (Licensing Opportunity)

0067 Milder Etchant for Penetrant Inspection—The etchant does not introduce artifacts that can be mistaken for defects. (Licensing Opportunity)

0068 Rolling Spot Welder—A wheeled tool speeds tack-welding operations.

0069 Simple, Internally Adjustable Valve—An adjustable orifice is made from two allen setscrews and an ordinary fitting.

Testing & Instrumentation

0070 Monitoring Both Sides of a Weld in Progress—Ultraviolet sources and cameras with image intensifiers would function despite brilliant arc light. (Licensing Opportunity)

0071 Monitoring Coating Thickness During Plasma Spraying—High-resolution video measures thickness accurately without interfering with the process.

Other Items of Interest

0042 Microbubble Flotation Development Unit

0076 Advanced Composite Pistons—Three-dimensional knitted fiber would yield improved mechanical properties. (Licensing Opportunity)

0080 Process for Autoclaving HMW PMR-II Composites—The qualities of autoclaved parts are equivalent to those of compression-molded parts.

0081 Making Self-Lubricating Parts by Powder Metallurgy—Thick parts can be made with minimal waste. (Licensing Opportunity)

0082 Shadow Moire Out-of-Plane Interferometric Damage Detector

Materials

0072 Magnetostrictive Materials (Licensing Opportunity)

0073 Polyphosphazene Semipermeable Membranes (Licensing Opportunity)

0074 Technique for Producing High-Strength Copper Alloys (Licensing Opportunity)

0075 Galvanized Steel Coating Systems Tested

0076 Advanced Composite Pistons—Three-dimensional knitted fiber would yield improved mechanical properties. (Licensing Opportunity)

0077 Computing Deformations of Rubbery Materials—Better use is made of experimental data in finite-element computations.

0078 Directional Solidification of Monotectic Alloys—Conditions that promote the formation of aligned fibres are sought.

0079 Low-Noise, Long-Life, High-Gain Microchannel-Plate Glass—Dark noise is reduced substantially without degrading other properties. (Licensing Opportunity)

0080 Process for Autoclaving HMW PMR-II Composites—The qualities of autoclaved parts are equivalent to those of compression-molded parts.

0081 Making Self-Lubricating Parts by Powder Metallurgy—Thick parts can be made with minimal waste. (Licensing Opportunity)

Testing & Instrumentation

0082 Shadow Moire Out-of-Plane Interferometric Damage Detector

0083 Holographic Reticle—This device could be used for noncontacting, nondestructive inspection of surfaces.

Other Items of Interest

0054 Ultrasonic Monitor to Determine Crack-Opening Load—Harmonics of acoustical signals are generated by cracks.

0063 Advances in Research on Powder Metal Manufacturing

0086 Porous Elastomer for Use in Vascular Grafts, Artificial Organs, Permeable Drug Delivery Systems, and Other Uses

0096 Behavior of Evaporating Liquid Drops in Clusters—Progress in understanding combustion of sprayed fuels and related phenomena is discussed.

Medicine & Biology

0084 Defining the Link Between Diet and Cancer Risk

0085 Treatment for Africanized Bee Stings Possible

0086 Porous Elastomer for Use in Vascular Grafts, Artificial Organs, Permeable Drug Delivery Systems, and Other Uses

0087 Center For Fast Kinetics

0088 Stand-Aid Invalid Wheelchair Designed

0089 Emulsions Containing Perfluorocarbon Support Cell Cultures—An additive reduces mechanical damage to cells, promoting denser growth. (Licensing Opportunity)

Medicine & Biology (Cont.)

0090 Indicator for Pseudomonas Bacteria—A characteristic protein is extracted and detected. (Licensing Opportunity)

Other Items of Interest

0034 Fireflies Light the Way to Improve Oil Yields

Natural Resources Technology & Engineering

0091 X-Ray Fluorescence Spectrometry Ore Available

0092 Preliminary Analysis of Data From AVIRIS—Radiometric calibration in flight and determination of reflectance of the ground are discussed.

Software

0093 Computer Program for Seismic Signal Analysis

Testing & Instrumentation

0094 Meteorological Data Systems to Track Balloon Borne Meteorological Radiosonde

Physical Sciences

0095 Method for the Recovery of Silver from Silver Zeolite (Licensing Opportunity)

0096 Behavior of Evaporating Liquid Drops in Clusters—Progress in understanding combustion of sprayed fuels and related phenomena is discussed.

0097 Concurrent Algorithm for Particle-in-Cell Simulations—Separate decompositions are used for the particle-motion and field calculations.

Testing & Instrumentation

0098 Analyzing Environmental Pollutants (Licensing Opportunity)

0099 Differentiating Mirror-Image Molecules (Licensing Opportunity)

0100 High-Temperature Quantitative Dilution Device for Oxides of Nitrogen Measurements via Chemiluminescent Monitors (Licensing Opportunity)

0101 Compensating for Doppler Shift in Laser Instrumentation—The frequency of a tunable diode laser is adjusted to oppose the shift. (Licensing Opportunity)

0102 Concentrating Gaseous Contaminants for Monitoring—Amounts of outgassed substances can be analyzed as functions of time and temperature.

0103 High-Pressure Promoted-Combustion Chamber—An improved version of an existing chamber would burn specimens in oxygen. (Licensing Opportunity)

Other Items of Interest

0057 Evaluation of an Anion Exchange Resin for Sampling Ambient Level Phenolic Compounds

0058 Laboratory Method to Estimate Hydrogen Chloride Emission Potential Before Incineration of a Waste

0059 Materials Can Help Evaluate Industrial Atmosphere

0087 Center For Fast Kinetics

0091 X-Ray Fluorescence Spectrometry Ore Available

0094 Meteorological Data Systems to Track Balloon Borne Meteorological Radiosonde

Transportation & Components

0104 Comparison of Calculations of Viscous Transonic Flow—Results of a variety of numerical simulations are compiled in a report for easy comparison.

0105 Measurement of Water Sprays Generated by Airplane Tires—Water sprays produced by tires on wet runways are simulated and analyzed.

0106 Predicting Unsteady Aeroelastic Behavior—The equations for the motion of the wing and the flow field are solved iteratively and simultaneously.

0107 Simulation of Three-Dimensional Supersonic Flows—Complicated flows can now be computed with fair accuracy.

Other Items of Interest

0048 Helmet-Mounted Visual Display for Flight Simulation—Optical fibers transmit wide-angle images in response to motions of the head. (Licensing Opportunity)

Agriculture & Food

0001 Insulation Impregnated Against Cockroaches

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0004 Tanks for Saving Water

Research Technology
Agricultural Research Service
U.S. Department of Agriculture

Insulation Impregnated Against Cockroaches

Impregnating insulation with cockroach repellants could be one strategy to cockroach-proof homes and commercial buildings in the future. Under a technology transfer agreement with ARS, Air Vent of Peoria, Illinois, will impregnate insulation with ARS-developed and patented cockroach repellants. The repellants are so strong that in tests, cockroaches choose to stay in bright light and starve to death rather than enter an area treated with the chemicals. ARS scientists will test the treated insulation in Florida homes with severe cockroach infestations. If it proves successful at keeping cockroaches away, it might be marketed by Air Vent's parent company, CertainTeed of Valley Forge, Pennsylvania. The cooperators envision builders installing the insulation in new homes so cockroaches will not invade them. For older homes, pest control operators could replace old insulation with the cockroach-repulsive type.

Insects Affecting Man and Animals Research Lab, Gainesville, FL
Richard J. Brenner, (904) 374-5937

New Tests Pinpoint Soy Compounds

Two natural compounds in soybean, known as trypsin inhibitors, can sabotage your body's ability to receive the full benefits of soy's high-quality protein.

Now, producers of soy-based diet shakes or infant formulas, soy flour, soy sauce, and related foods can use two new assays to find out if any active trypsin inhibitors remain in their products after conventional processing.

The tests, developed by David L. Brandon, Anne H. Bates, and Mendel Friedman with ARS' Food Safety Unit in Albany, California, give more accurate results that other techniques for detecting the Kunitz or Bowman-Birk inhibitors.

Unlike earlier tests, each assay can accurately distinguish one inhibitory compound from the others, and can detect them even in very small amounts, Brandon says.

Both tests rely on proteins called monoclonal antibodies to seek out and bind to the inhibitors. Brandon and colleagues produced the new monoclonal antibodies initially in laboratory mice, then in cells kept alive in the laboratory.

In addition to soy processors, Brandon notes that other groups might be interested in the new assays. Plant breeders who want to develop soybean varieties naturally low in both inhibitors could use the tests to check new strains.

Researchers who are trying to sort out conflicting claims about the effects of the inhibitors should find the antibodies useful. That group may include scientists who are following up on studies, first reported in 1983, that showed that the Bowman-Birk inhibitors had cancer-fighting effects in laboratory animals.

FOR ADDITIONAL INFORMATION: For technical information about these patents contact David L. Brandon, USDA-ARS, Food Safety Research Unit, Western Regional Research Center, 800 Buchanan St., Albany, CA 94710 (415)559-5783, Patent Serial No. 07/101,918, "Monoclonal Antibodies to Soybean Kunitz Trypsin Inhibitor and Immunoassay Methods" and Patent Serial No. 07/246,842, "High Affinity Monoclonal Antibodies to Bowman-Birk Inhibitor and Immunoassay Methods."

Research Technology
Agricultural Research Service
U.S. Department of Agriculture

Spotting Swine Dysentery

Some little pigs don't make it to market because of swine dysentery. This debilitating disease, also known as black or bloody scours, causes severe intestinal lesions and diarrhea. It usually occurs in pigs 8 to 14 weeks old, although older pigs are sometimes affected.

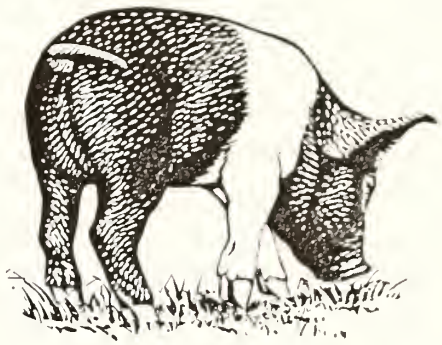
Pigs infected with swine dysentery become dehydrated and don't gain weight—and, to a producer, weight is money. Although it's not usually a killer, the disease causes serious economic losses.

The disease is caused by the spirochete bacterium, *Treponema hyodysenteriae (T. hyo)*. Animals that recover from the disease may still harbor the spirochete without showing disease symptoms.

"Quick diagnosis can be critical to control of swine dysentery," says Neil S. Jensen, ARS microbiologist at the National Animal Disease Center in Ames, Iowa. Current laboratory diagnostic tests rely on culturing fecal samples, a process that can take from 4 to 6 days.

"But in that time, the quick-spreading disease could render a pig operation nonproductive," says Jensen. Besides being slow, culturing techniques are not always able to distinguish *T. hyo* from other non-pathogenic spirochetes, such as *T. innocens* and *T. succinifaciens*, which may also be found in the pig's intestine.

Jensen and coworker Thad B. Stanton developed a DNA probe



that can detect *T. hyo* in pig fecal samples. With it, an accurate diagnosis of swine dysentery can be made in 1 to 2 days.

The probe is a single strand of DNA that binds to the ribosomal RNA of *T. hyo*. The probe contains a radioactive tag making its binding to the target RNA detectable by exposure to x-ray film.

A region of the ribosomal RNA of the disease-causing spirochete has a sequence, "like a signature—unique to that organism," says Jensen. The probe binds to that signature sequence and, in doing so, unmistakably identifies the spirochete.

The pork industry has expressed interest in ridding the United States of swine dysentery. This diagnostic test could help convert such concern into a workable eradication program.

Neil S. Jensen and Thad B. Stanton are at the National Animal Disease Center, P.O. Box 70, Ames, IA 50010 (515) 239-8288. ◆

Research Technology
Agricultural Research Service
U.S. Department of Agriculture

Tanks for Saving Water

Simple, cheap, easy-to-make-at-home covers for livestock water supplies are cutting water losses at more than 100 locations in the United States.

"Throughout much of the West, the covers can prevent up to 4 feet of water from evaporating each summer from open-top, vertical-walled storage tanks. Even more water is saved in warmer climates," says Allen R. Dedrick, ARS agricultural engineer at the U.S. Water Conservation Laboratory, Phoenix, Arizona, who pioneered the research in the early 1970's.

The covers are made from rolls of 1/4-inch-thick by 4-foot-wide foam rubber that is light enough to float on water but heavy enough not to be blown off by normal winds. Cutting and bonding with contact adhesive, it takes two workers about 3 hours to construct a cover that's 30 feet in diameter.

They cut 1/2-inch-diameter holes every 3 to 4 feet along each sheet to allow rainfall to drain into the tank. In particularly windy areas, the edges can be weighted to keep the wind from flipping the covers off the tanks and wires can be stretched across the top.

According to a recent followup survey, the covers have withstood the ravages of weather up to 10 to 15 years.

"Wildlife managers are enthusiastic about the cover because they serve as watering rafts for birds. I've seen hundreds of doves around the tanks and floating on the covers," says Dedrick.

He continues to fill requests for instructions to build the covers.

Allen R. Dedrick is in USDA-ARS Irrigation and Hydraulics Research, U.S. Water Conservation Laboratory, 4331 E. Broadway Road, Phoenix, AZ 85040 (602) 379-4356. ◆

Computers

Software

0005 Program Manipulates Plots for Effective Display—Plots can be displayed in a variety of useful ways.

0006 Risk Assessment the DOE Way

0007 Balancing Loads Among Parallel Data Processors—A heuristic algorithm minimizes the amount of memory used by a multiprocessor system. (Licensing Opportunity)

0008 Bus-Programmable Slave Card—A specialized microprocessor development system is not necessary. (Licensing Opportunity)

0009 Truncation of Images for Correlation—Correlation could be performed on a relatively small computer. (Licensing Opportunity)

Other Items of Interest

0028 Starting Circuit for Erasable Programmable Logic Device—The voltage regulator is bypassed to supply the starting current.

0064 Checking Automated-Welder Programs by Computer—A personal-computer-based system, distinct from the welding-control computer, finds software errors.

Program Manipulates Plots for Effective Display

Plots can be displayed in a variety of useful ways.

The Windowed Observation of Relative Motion (WORM) computer program is primarily intended for the generation of simple X-Y plots from data created by other programs. It enables the user to label, zoom, and change the scales of various plots. Three-dimensional contour and line plots are provided, but with more limited capabilities. The input data can be in binary or ASCII format, but all data must be in the same format. A great deal of control over the details of the plot is provided, such as gridding, the size of tick marks, colors, log/semilog capability, time tagging, and multiple and phase-plane plots. Many color and monochrome graphics terminals and hard-copy printer/plotters are supported.

The executive commands, menu selections, and macro files of WORM can be used to develop plots and tabular data, query the WORM Help library, retrieve data from input files, and invoke VAX DCL commands. Plots generated by WORM are displayed on local graphics terminals and can be copied by use of standard hard-copy capabilities. The graphics features of WORM include the following: zooming and dezooming various portions of the plot; documentation of the plot, including labeling of curves and listing of functions; multiple curves on the same plot; windowing of multiple plots and insets of the same plot; displaying a specific point on a curve; and spinning the curve left, right, up, and down for three-dimensional contour plots.

WORM is written in PASCAL for interactive execution and has been implemented on a DEC VAX computer operating under VMS 4.7 with a virtual-memory requirement of approximately 392K of 8-bit bytes. It uses the QPLOT device-independent graphics library, which is included with it. Full WORM graphics capabilities are supported for various Tektronix 40XX and 41XX terminals and PC and Macintosh terminal emulators. WORM was developed in 1988.

This program was written by F. Bauer and J. Downing for **Goddard Space Flight Center.**
GSC-13232/TN

FOR ADDITIONAL INFORMATION

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112 Barrow Hall
University of Georgia
Athens, GA 30602

(404) 542-3265

NIST Technology Update

National Institute of Standards & Technology

U.S. Department of Commerce, Gaithersburg, MD 20899

Risk Assessment the DOE Way

An important part of developing a computer security program is weighing the costs of controls against the risk of loss. Controls that are more expensive than the information they protect are not cost-effective. To help achieve a balance, NIST is investigating ways to identify risks and select appropriate cost-effective computer security measures. That includes making available information on methods developed by other federal agencies. NIST recently reprinted a publication describing the risk assessment method used by the U.S. Department of Energy (DOE). The DOE approach specifies six steps, including defining the system, software, and data; identifying threats; selecting countermeasures; and obtaining management review, participation, and accountability. Included in the publication are worksheets and tables needed to carry out each step. Also included is a sample completed worksheet, a bibliography, and a glossary.

FOR ADDITIONAL INFORMATION: A copy of the report is available from NTIS, Springfield, VA 22161; (703)487-4600.

NTIS order number: PB90-244484NAC

Price code: A09

NASA Tech Brief
National Aeronautics and Space Administration
Lyndon B. Johnson Space Center, Houston, Texas

Balancing Loads Among Parallel Data Processors

A heuristic algorithm minimizes the amount of memory used by a multiprocessor system.

Algorithms may distribute the load of many identical, short computations among multiple parallel digital data processors, each of which has its own (local) memory. Each processor operates on a distinct and independent set of data in a larger shared memory. As an integral part of the load-balancing scheme, the total amount of space used in the shared memory is minimized. Possible applications include artificial neural networks or image processors for which the "pipeline" and vector methods of load balancing may be inappropriate.

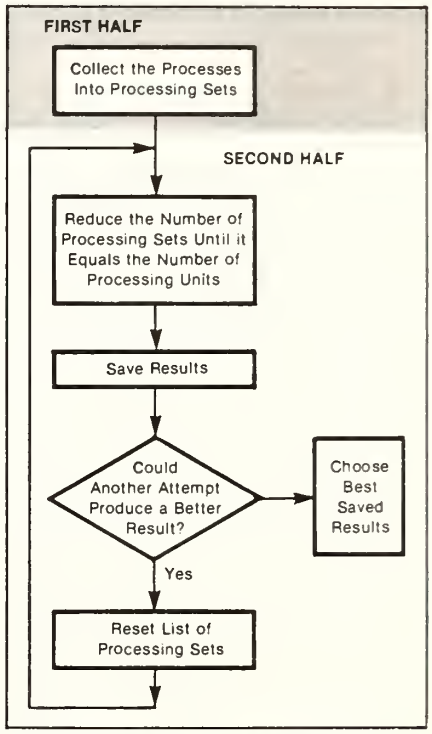
TERMS: A **process** is a computation and/or other operation upon **total memory**, which is the sum of all shared memory, both source (read but not changed) and **target** [changed by some process(es)]. A memory **partition** is a disjoint subset of either source or target memory (but not both) sharing no members with any other subset. A **partition threshold** is some number of partitions that represent the current maximum memory size allowed for a **processing set**, or collection of processes. **Load** is a number proportional to the time it takes to complete the process. The desired load is the **balance load**, equal to the sum of all loads divided by the number of processing units.

The first half of the algorithm (see figure) collects processes into processing sets. First, a two-dimensional array or "grid" of the shared memory is created, with source memory on one axis and target memory on the other. Next, values are placed at each intersection of source/target-memory pairs to represent the load (or section of load) of the process that operates upon that source/target pair. Then source and target memories are divided on the grid, creating rectangular regions with one source and one target partition, so that no process is spread across two regions. Regions are then sorted in terms of the sum of the loads included within their bounds. Any regions exceeding the balance load are split into equal parts, each with the same source/target-partition pair and no more than the desired balance load.

The second half of the algorithm performs mergers of processing sets by combining one processing set at a time with another set that can take on some or all of the load. This is repeated until the total number of sets equals the number of processing units. First, the smallest processing set, **S**, is chosen. "Merge candidates" are found among all other processing sets that have loads smaller than the balance load. Any merge that would exceed the partition threshold is discarded. Of the remaining candidates, the one that has the most partitions in common with **S** is chosen as the target for merge.

Execution of the algorithm is very quick when a small number of partitions is used (the first half of the algorithm runs in linear time; the second half runs in constant time). Thus the second half of the process can be repeated several times, each with a different starting partition threshold, and the "best" (or lowest threshold) solution chosen. Because the algorithm uses such a simple merging heuristic, it is not possible to generalize an ideal starting partition threshold. Making multiple runs of the algorithm is the only way to obtain the best result.

This work was done by Paul Thomas Baffes of **Johnson Space Center**.


FIRST HALF
Collect the Processes Into Processing Sets
SECOND HALF
Reduce the Number of Processing Sets Until it Equals the Number of Processing Units
Save Results
Could Another Attempt Produce a Better Result?
Choose Best Saved Results
Yes
Reset List of Processing Sets

The **Main Steps of the Algorithm** can be considered to be divided into a first half and an iterative second half. The result of the iteration is a balancing of computational load (including memory) among the processors of a parallel multiprocessor system.

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Johnson Space Center. Refer to MSC-21348/TN.

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration
Lyndon B. Johnson Space Center, Houston, Texas

Licensing Opportunity

Bus-Programmable Slave Card

A specialized microprocessor development system is not necessary.

A slave microprocessor in a multimicroprocessor computing system contains modified circuit cards that can be programmed via the bus that connects the master processor with the slave microprocessors. Although slave cards in multimicroprocessor systems of recent design are programmable via the master/slave buses, those of a slightly older generation of equipment are not. Heretofore, it has been necessary to use specialized microprocessor development equipment to program the older cards. The modified cards eliminate the need for this equipment and increase the flexibility of operation.

The bus-programmable slave card is made possible by the recent introduction of tristate, high-density circuitry and 5-V electrically-erasable, programmable, read-only memories (EEPROM's), which were not available when most of the slave systems now on the market were designed. It includes 64 Kbytes of EEPROM, a real-time clock, a four-channel analog-to-digital converter, eight channels of high-power relay-type devices, and a slave-card central processing unit, which incorporates the capability for programming via the bus and controls the bidirectional communication between the master and slave. One of the following three optional features can also be installed on the card: an additional four-channel analog-to-digital converter, a circuit to enable communication via a standard RS232 bus, or a digital-to-analog output (see Figure 1).

The bus-programmable slave card offers two modes of operation. The first is the general-run mode, which characterizes the logic state of the card during most operations. The second is the programming mode, in which the card is programmed from the bus.

In the general-run mode, the slave card acts as a single-loop slave processor to the master central processing unit. As a slave, it never gets on the bus. The card is totally self sufficient and is capable of running its own input and output as well as transfering data to and from the bus. As shown in Figure 2, all data and status information is latched in by tristate buffers. In addition, the master can reset the slave card at will. If the slave is reset, then it idles, waiting for a "start program" execution command from the master card. The slave card does not require any modification of the operating system and gives the user 63K of programming space, which can be configured as either electrically-programmable or random-access memory in 8K blocks by a simple selection of jumpers, without exchanging circuit chips or using outside voltage sources.

In the programming mode, the user flips a switch, sending the slave into tristate suspension while its memory is imaged to the bus. At this stage, the user loads the application program into the memory of the master by using DDT, an error-correcting computer program for the CP/M operating system. Once the program is loaded, the switch is closed and the slave is released. The master central processing unit is free to leave DDT and continue other activities. The slave card can be programmed with a 16 K ".COM" file in less than 4 seconds, compared to more than 13 minutes when serial loading methods are used. Once loaded, the program can then be treated as residing in either random-access or read-only memory, depending on the selection of jumpers. At this point, the slave monitors the status port for a command to start executing the program. It loops endlessly until it receives the command.

This work was done by William A. Hall of Krug International for **Johnson Space Center.**

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Johnson Space Center. Refer to MSC-21387/TN.

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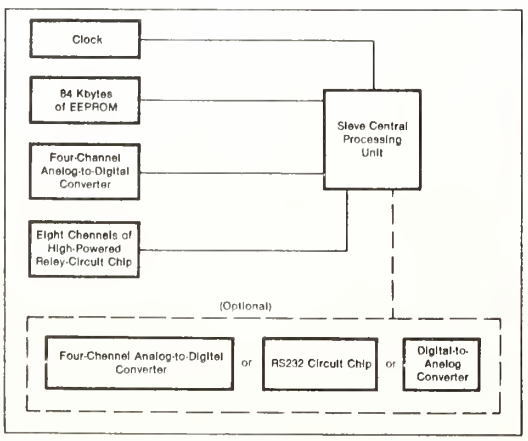

Figure 1. The **Bus-Programmable Slave Card** enables interactive, microprocessor-based, single-loop control. It confers the ability to load and run a program from the master/slave bus, without the need for a microprocessor development station.

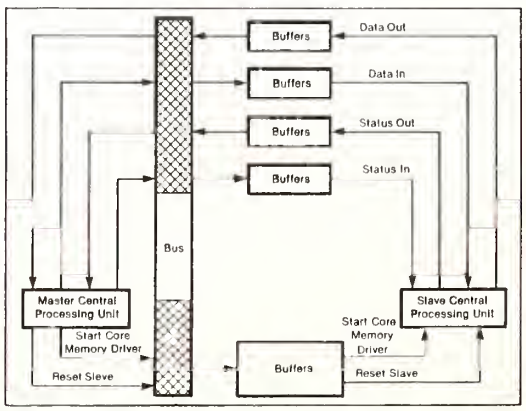

Figure 2. **Tristate Buffers** latch all data and information on status. The slave central processing unit is never connected directly to the bus.

NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Licensing Opportunity

Truncation of Images for Correlation

Correlation could be performed on a relatively small computer.

As part of a proposed method for processing video images in slowly changing scenes, renditions of complicated objects would be truncated to points, lines, polygons, or other simplified geometrical objects. The truncated images would be processed by image-correlating algorithms to extract information; for example, to recognize features and to track the displacements of features in subsequent image frames to determine velocities. The principal advantage of the truncated images is that they would entail the correlation of far fewer data than the original images would. Thus, correlations could be performed on relatively small computers or, alternatively, much more rapidly on larger computers.

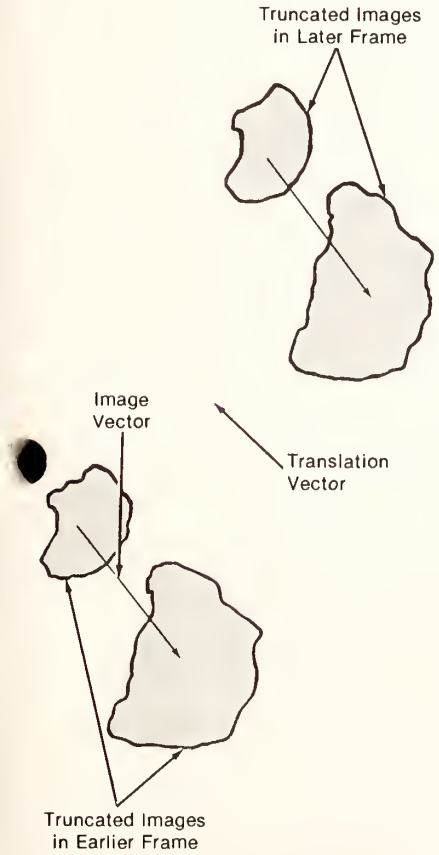

Figure 1. A **Vector Between Contours** in a truncated image translates to a new position in a subsequent frame. The translation vector is proportional to the velocity of the object(s) represented by the contours.

The image recorded on a charge-coupled-device or other suitable camera during a frame period would first be subjected to a thresholding operation so that up to three salient features could be selected for further processing. The selected features would then be turned into contours when the surviving picture elements form an assembly of closed lines, or else would be represented by straight lines connecting pairs of end picture elements when the surviving picture elements do not form closed lines. Next, the positions of the centroids of the areas enclosed by the contours and/or the midpoints of the straight lines would be calculated and recorded. Computations for further truncation and use of the already truncated images would then begin.

Figure 1 illustrates an example of such further processing of a truncated image that consists of contours of two objects. First, a straight line would be constructed between the centroids enclosed by the two contours. This line would be a vector of known length and direction. The translation and rotation of the vector to new positions and orientations in subsequent image frames could be used to compute the velocity of relative motion between the camera and the two objects represented by the contours.

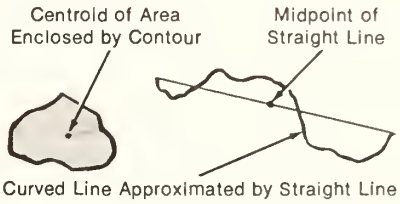

Figure 2. A **Curved Line Is Represented by a Straight Line**, and its position is represented by the midpoint of the straight line.

Figure 2 illustrates an example in which an open line is represented by a straight line between its end points and a closed contour is also present. In this case, the vector used to detect motion would be drawn from the centroid of the area enclosed by the contour to the midpoint of the straight line.

This work was done by Katsunori Shimada of Caltech for **NASA's Jet Propulsion Laboratory.**

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, NASA Resident Office-JPL. Refer to NPO-17847/TN.

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REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

Electrotechnology

0010 RADC-SCAT An Automated Sneak Circuit Analysis Technique
0011 Fiber Optic Connectors
0012 Electromagnetic Properties of Superconductors
0013 Metallized Synthetic Cable Developed
0014 Navy Reviews Teletouch Display Development
0015 Simple Monopole Inductively Loaded Antenna System Developed
0016 Active Limiters for Photodetectors—Intense radiation would trigger protective electro-optical shutters.
0017 Dielectric-Filled Paraboloidal Front Ends—Planar antennas with receiving and/or transmitting circuits are integrated at the focal point.
0018 Calculating Performances of Fabry-Perot Etalons—Effects of changes in design can be determined quickly.
0019 Directional Couplers for Detecting Circular Waveguide Modes—Samples of TE(11) and TE(12) modes are coupled selectively out of a circular waveguide.
0020 Effects of Dose Rates on Radiation Damage in CMOS Parts—Damage is more severe at lower dose rates.
0021 High-Efficiency Klystron for Television Transmitters—A multistage depressed collector recycles energy from spent electrons.
0022 MCT/MOSFET Switch—A hybrid of two different switching transistors has large safe operating area and high speed. (Licensing Opportunity)
0023 Millimeter-Wave Quantum-Well Frequency Multipliers—A double-barrier quantum-well GaAs diode produced 0.25 mW output at the third harmonic, 191 GHz. (Licensing Opportunity)
0024 More About Lens Antenna for Mobile/Satellite Communication—Details of a flat phased-array design are presented.
0025 Phase Calibration of Radar Polarimetric Data—Calibration parameters are extracted from the data themselves.
0026 Planar Microstrip Yagi Antennas—Mutual coupling between microstrip elements, ordinarily considered a nuisance, is used to advantage. (Licensing Opportunity)
0027 Real-Time Digital Compression of Television Image Data—Broadcast-quality images can be transmitted at low data rates. (Licensing Opportunity)
0028 Starting Circuit for Erasable Programmable Logic Device—The voltage regulator is bypassed to supply the starting current.
0029 Self-Aligned Guard Rings for Schottky-Barrier Diodes—The active area would be increased. (Licensing Opportunity)
0030 Switching Matrix for Optical Signals—Size, weight, and power consumption would be reduced. (Licensing Opportunity)

Testing & Instrumentation

0031 Diffraction Analysis of Distorted Reflector Antennas—The effects of systematic distortions of surfaces on radiation patterns are predicted.
0032 Computing Scattering Matrices for Circular Waveguides—This program computes scattering at junctions between sections on a common axis.

Other Items of Interest

0037 Copper Chloride Cathode for Liquid-Sodium Cell—Energy density is higher than that of previous liquid-sodium cells. (Licensing Opportunity)
0053 Shaft-Rotation Detector—Rotation is deduced from a subtle component of vibration. (Licensing Opportunity)
0101 Compensating for Doppler Shift in Laser Instrumentation—The frequency of a tunable diode laser is adjusted to oppose the shift. (Licensing Opportunity)

Department of Defense
Reliability Analysis Center

Rome Air Development Center, Griffiss AFB, NY 13441

RADC-SCAT An Automated Sneak Circuit Analysis Technique

Sneak Circuits - a circuit path that causes the occurrence of an unwanted function or inhibits a desired function even though all components function properly... (MIL-STD-1543B).

They were called "gremlins". Pilots used this term to explain the untraceable failures that plagued their aircraft during World War II. It was not until the complex systems of the space program were analyzed that these gremlins were identified as hidden paths designed into the electronics. These design flaws are known today as sneak circuits.

Sneak Circuit Analysis (SCA) was pioneered by the Boeing Corporation as part of their work on the Apollo space project. Over the years "clue lists" were developed by Boeing and other specialists. These clue lists are used to search for and identify sneak paths. The problem that exists today is that many of these clue lists are proprietary meaning only a select number of specialists have the capability to perform a sneak circuit analysis. RADC is hoping to correct this situation with the introduction of RADC-SCAT (Sneak Circuit Analysis Technique).

Under contract with RADC, SoHaR Incorporated, Beverly Hills, CA, has produced a PC-based software package that performs a sneak circuit analysis (SCA) and scans for 17 design concerns. This package scans schematic netlists for reverse current sneak paths. Once a sneak path has been found, SCAT gives a brief description of the weakness to the user and will even offer a sample solution to the problem. The approach taken by the RADC-SCAT package corrects many of the deficiencies present in the traditional SCA procedure. A limited number of copies of the demo disk and booklet are available from RADC.

There are many shortcomings in today's sneak testing methods. To test for sneaks today, a specialist must be hired to screen the design for damaging sneaks. These specialists are very expensive and must spend much of their time just becoming familiar with the design. An outside specialist also requires a high level drawing to analyze, meaning analysis may not begin until production has been started, often too late to take any corrective action. The result of this situation would be a reworking of the completed hardware, a redesign of the system blueprints, and even a possible recall of any delivered pieces.

SCAT is designed to correct these deficiencies and make sneak circuit analysis a commonplace, cost-effective technique. Since SCAT is PC-based, it is easy to use and can readily be applied early in the design phase. Performing a sneak circuit analysis at this time would insure that potential sneaks do not advance into production. Outside contractors are not necessary because SCAT is used by the actual designers, saving both time and money and avoiding any confrontation between designers and contractors on design flaws. Also, by pointing out the weaknesses of an electrical network, the designer is educated by SCAT on how to avoid sneak conditions in future projects.

The operation of the SCAT demo-disk requires two commercial software products. The *M.1 Expert System* allows the user to run the SCAT demonstration program. The user may also input his/her own circuits for analysis by using the *OrCAD Schematic Capture Program* which generates the netlist that is analyzed by SCAT. Information on this software is available through RADC.

The RADC-SCAT package includes a description of the operation of SCAT, a listing of sample sneak conditions along with their possible solutions, and a copy of the demo disk. SCAT does not perform a complete sneak circuit analysis at this time, as it is now at the demonstration stage. However, the RADC-SCAT demo disk identifies reverse current sneak paths and scans for 17 of 80 design concerns listed in MIL-STD-1543B.

Written requests for the RADC-SCAT DEMO-DISK should be sent on company letterhead to: Edward DePalma, RADC/RBER, Bldg. 3 Griffiss AFB, NY 13441-5700, Telephone (315) 330-2702.

U.S. Army Fact Sheet

Fiber Optic Connectors

A technique has been developed that relates to fiber optic connector keying arrangements. These arrangements prevent the unintended mixing of traffic when a plurality of similar fiber optic cables are to be interconnected with electronic equipment handling traffic of various types and classifications.

The technique has been laboratory proven and is being considered for possible use by the United States Army.

The technique can be used for any communication system or network where a plurality of electronic equipment are interconnected to achieve desirable telecommunications configurations. The technique is most useful for performing interconnections in the absence of light or within adverse environmental conditions.

Patent status: U.S. Patent Number 4,875,753.

FOR ADDITIONAL INFORMATION: Charles Grzenda, Chief, Office of Research and Technology Applications, Center for C3 Systems, Attn: AMSEL-RD-C3-PB, Fort Monmouth, NJ 07703, Telephone: (201) 544-3119.

Electromagnetic Properties of Superconductors

Designers and builders of high-energy physics magnets (including those for the Superconducting Super Collider) and of nuclear magnetic resonance instruments need data on the performance of superconductors and high-permeability steels. NIST has studied the effects on the superconductor critical current of mechanical loading and of the deformation resulting from fabrication. NIST also has evaluated the magnetic properties of several types of steel allows used in these magnets and instruments. A report, *Electromechanical Properties of Superconductors for High Energy Physics Applications, Part II* (NISTIR 89-3912), describing NIST's findings is available.

FOR ADDITIONAL INFORMATION: A copy of the report is available from NTIS, Springfield, VA 22161; (703)487-4600.

NTIS order number: PB90-163627NAC
Price code: A07

Metallized Synthetic Cable Developed

Scientists at the Naval Ocean Systems Center (NOSC), San Diego, California, have developed a lightweight, neutrally buoyant cable, which is ideally suited for electronic undersea data link communications.

The cable consists of a bundle, containing anywhere from one to any practicable number, of continuous synthetic fibers, each about 10 microns in diameter and coated with a metallic layer extending the entire desired length. This is all covered by a dielectric insulative layer and, optionally, an outer conductor.

The size of the undersea link is variable to accommodate different frequency responses, and the material of the metallized layers is variable to allow for different weights and desired transmission characteristics, which will accommodate a variety of undersea systems. This capability gives designers a wide latitude for responsively monitoring remote sensors to assure that the gathered signals are not compromised by the transmission paths.

For Additional Information:

Backup material on this effort is available from:

Navy Domestic Technology Fact Sheet Reader Reply Service
Code E211
Naval Surface Weapons Center
Dahlgren, VA 22448-5000
(703) 663-8921

Refer to 150405/TN

Navy Reviews Teletouch Display Development

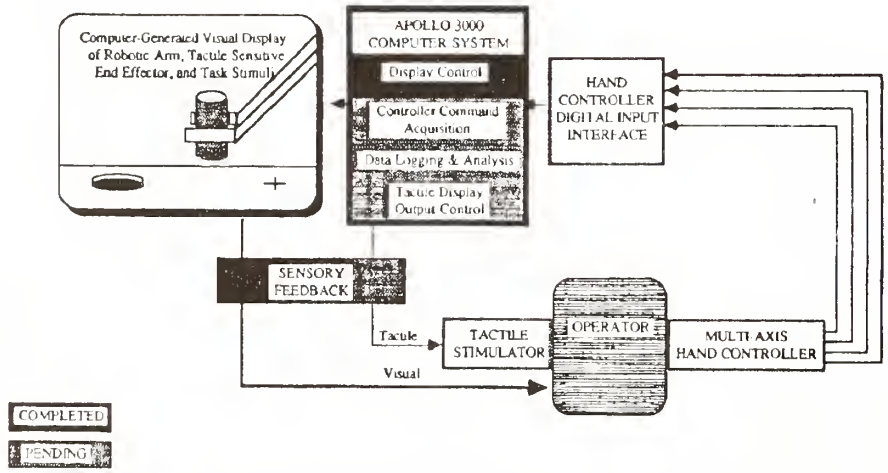

Figure 1. Tactile-display develoment of an experimental apparatus

Human-tactual capabilities and previous efforts in tactile-display development (see Figure 1) have been reviewed by the Naval Ocean Systems Center (NOSC), San Diego, California, and approaches are recommended for developing teletouch-display systems for telerobotic systems.

Teleoperated manipulators currently in use rely mainly upon visual feedback to accomplish simple manipulation tasks. In some cases to enhance manipulative capabilities, force reflection and positional correspondence are provided between slave manipulator and master controller arms, along with simple end-effector proximity and slip sensors.

Impressive developments in contact-force transduction have occurred over the past decade. A few experimental devices have demonstrated sensing capabilities exceeding several criteria viewed as ideal not more than a few years ago. However, significant development hurdles still remain to be cleared in transducing and extracting information from tactile-sensor inputs.

Present algorithms are efficient only for simple manipulation tasks or when using a highly constrained search space for object identification. Increasing the difficulty of object identification or relying upon multiple tactual cues to complete complex manipulations, demands human intervention to fuse, selectively filter sensor information, construct and test precepts, and to plan and execute control over manipulators.

For Additional Information:

Backup material on this effort is available from:

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Naval Surface Weapons Center
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Refer to 150401/TN

Simple Monopole Inductively Loaded Antenna System Developed

A simple method of tuning an inductively loaded whip antenna over an extended band of frequencies has been developed by a scientist at the Naval Ocean Systems Center (NOSC), San Diego, California (see Figure 2). The method is ideal for inexperienced operators or an automated tune-up procedure because only two adjustments are required. The adjustment procedures are to resonate the antenna with a capacitor and to select a matching transformer for minimum VSWR. A number of matching transformers are designed into the system so that an acceptably low VSWR is obtained for the range of resonated impedances over the frequency band.

The present invention is particularly suitable for use in marine environments or where it is impracticable or impossible to make physical changes to the antenna element itself or to the antenna loading coil. Further, no tap conditions on the inductive load of the antenna element are necessary, and the use of motors and/or mechanical control shafts in the vicinity of the inductor are not required.

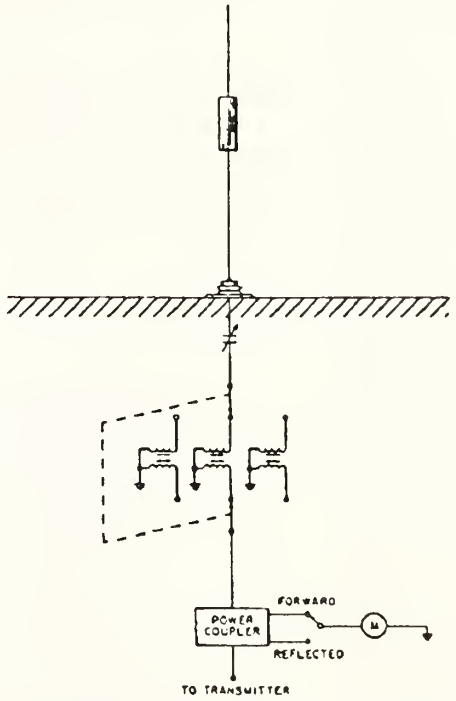

Figure 2. Inductively loaded whip antenna

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Refer to 150402/TN

NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Active Limiters for Photodetectors

Intense radiation would trigger protective electro-optical shutters.

Active or "smart" electro-optical shutters have been proposed for the protection of photodetectors, imaging devices, and other sensitive optical or optoelectronic elements. Such a shutter would respond rapidly and automatically to an increase in illumination above a prescribed level.

To illustrate the principle of operation, Figure 1 shows one version of a shutter that would protect a sensor against intense laser light. A beam splitter would divert a small portion of the incoming laser beam to a crude spectrometer consisting of a grating or other wavelength-dispersive element and a linear array of relatively insensitive photodetectors that are rugged enough to withstand the maximum irradiance likely to be encountered in the laser beam. The major part of the incoming laser beam would pass through the beam splitter and an electro-optical switch on the way to the protected sensor.

Processing electronics would monitor the output of the spectrometer along with control input signals. If the total irradiance or the spectral radiance at the wavelength of interest, as measured by the spectrometer, were to rise above the threshold prescribed as the maximum safe level for the protected sensor, the processing electronics would activate an amplifier, which would apply a high voltage (typically of the order of 1 kV) to the electro-optical switch to turn it opaque.

The spectrometer (as opposed to a simple photodetector) would be needed because the voltage V_π required to turn an electro-optical switch opaque depends on the wavelength, λ:

$$V_\pi = \lambda/2n^3r$$

where n represents the index of refraction in the electro-optical crystal in the switch and r represents the electro-optical coefficient of this crystal. The processing electronics and the amplifier would generate V_π according to this equation, using λ as measured by the spectrometer.

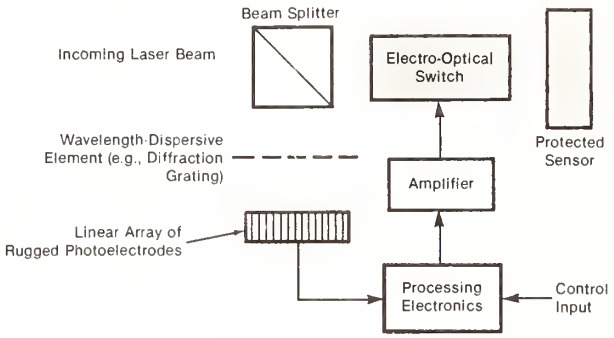


Figure 1. This **"Smart" Limiter** would be an active electro-optical shutter that would protect a sensor against an excessively bright laser beam. Because the shutter would include a spectrometer, it would not be necessary to know the wavelength of the laser light in advance.

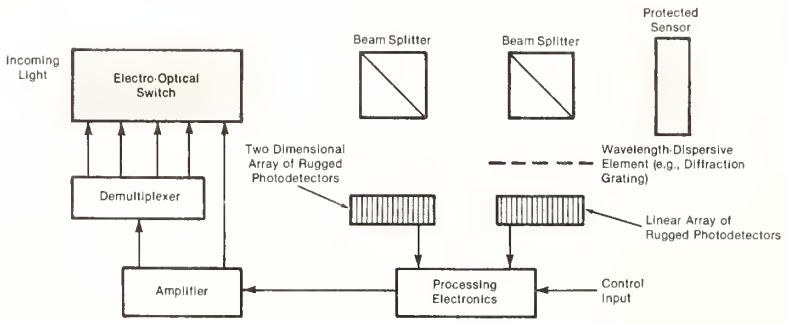


Figure 2. **Spatial Discrimination** would be added to spectral discrimination in this "smart" limiter. Selected portions of the cross-section incoming beam of light could be blocked to prevent damage to the corresponding portions of the protected sensor.

A more complicated shutter (see Figure 2) could be built to protect selected portions of an imaging sensor. This shutter would include another beam splitter to divert a small portion of the incoming light to a two-dimensional array of rugged photodetectors. In this system, the electro-optical switch would include a two-dimensional array of pairs of switching electrodes corresponding to the array of rugged photodetectors. If the light falling on such a detector were to rise above the threshold, V_π would be applied to the corresponding pair of electrodes to prevent the light from reaching the corresponding portion of the protected sensor.

To provide effective protection, the active limiter would have to respond before the irradiance reached a harmful level. Using currently available equipment, it is now possible to attain response times of the order of nanoseconds. If even this short a response time is still too long, a delay line — perhaps a bundle of optical fibers — could be inserted between the protected sensor and the last stage of the limiter.

This work was done by Joseph Katz and Li-Jen Cheng of Caltech for **NASA's Jet Propulsion Laboratory.**
NPO-17654/TN

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Dielectric-Filled Paraboloidal Front Ends

Planar antennas with receiving and/or transmitting circuits are integrated at the focal point.

Reflectors formed from shaped dielectric material with a metallized parabolic surface can serve as the basis for a wide variety of planar, integrated receiver and transmitter circuits operating at millimeter and submillimeter wavelengths.

At short wavelengths, it is desirable to be able to integrate a receiver or transmitter circuit with a planar antenna and beam-shaping optics to produce an easily fabricated, compact and robust structure to serve as the front end of a much larger radio-frequency (RF) telescope system. At microwave and millimeter-wave frequencies, a waveguide generally has been the medium of choice for coupling energy into or out of the receiver or transmitter element, and a feed horn has usually been used to match efficiently onto the main collecting surface. At higher frequencies (above 350 GHz), waveguide devices are very difficult to fabricate, and suitable alternatives have been sought for some years.

The dielectric-filled parabola takes advantage of the fact that an antenna on a dielectric half-space radiates preferentially into the dielectric. It combines an input feed (planar antenna), transmitting or receiving element (integrated detector, mixer, or oscillator diode), bias and/or intermediate-frequency lines and beam-forming optics into a single robust structure. The main component is a planoconvex dielectric lens with the convex surface shaped into a parabola having an f/D (focal-length-to-diameter) ratio of 0.25. The parabolic face is metallized, and a planar antenna and receiver (or transmitter) element are integrated onto the center of the flat surface of the dielectric lens, the focal point of the parabola.

A heterodyne array receiver front end using a dielectric-filled parabola is shown in the figure. Radiation is incident on the flat surface of the dielectric, presumably but not necessarily from some larger collecting-area dish or telescope. The incoming beam passes through the dielectric, reflects off of the metallized parabolic face, and is focused onto the antenna array on the planar surface of the lens. The antenna elements couple the RF radiation directly to the detectors or downconverting devices located at the terminals. Intermediate frequency removal and direct-current (DC) biasing are accomplished using coplanar lines (other transmission-line media are of course possible), which are integrated on the dielectric surface at the same time as the antenna elements. These include low-pass filter elements to remove the detection or mixing products without affecting the RF antenna characteristics. Connections to external circuitry are made at the edge of the dielectric lens through bond wires attached to pads at the ends of the coplanar line. For heterodyne operation, the local-oscillator signal can be injected through a hole left for this purpose at the center of the metallized surface of the lens.

For a dielectric with a high index of refraction, a quarter-wavelength-thick matching layer is added on the flat surface of the lens.

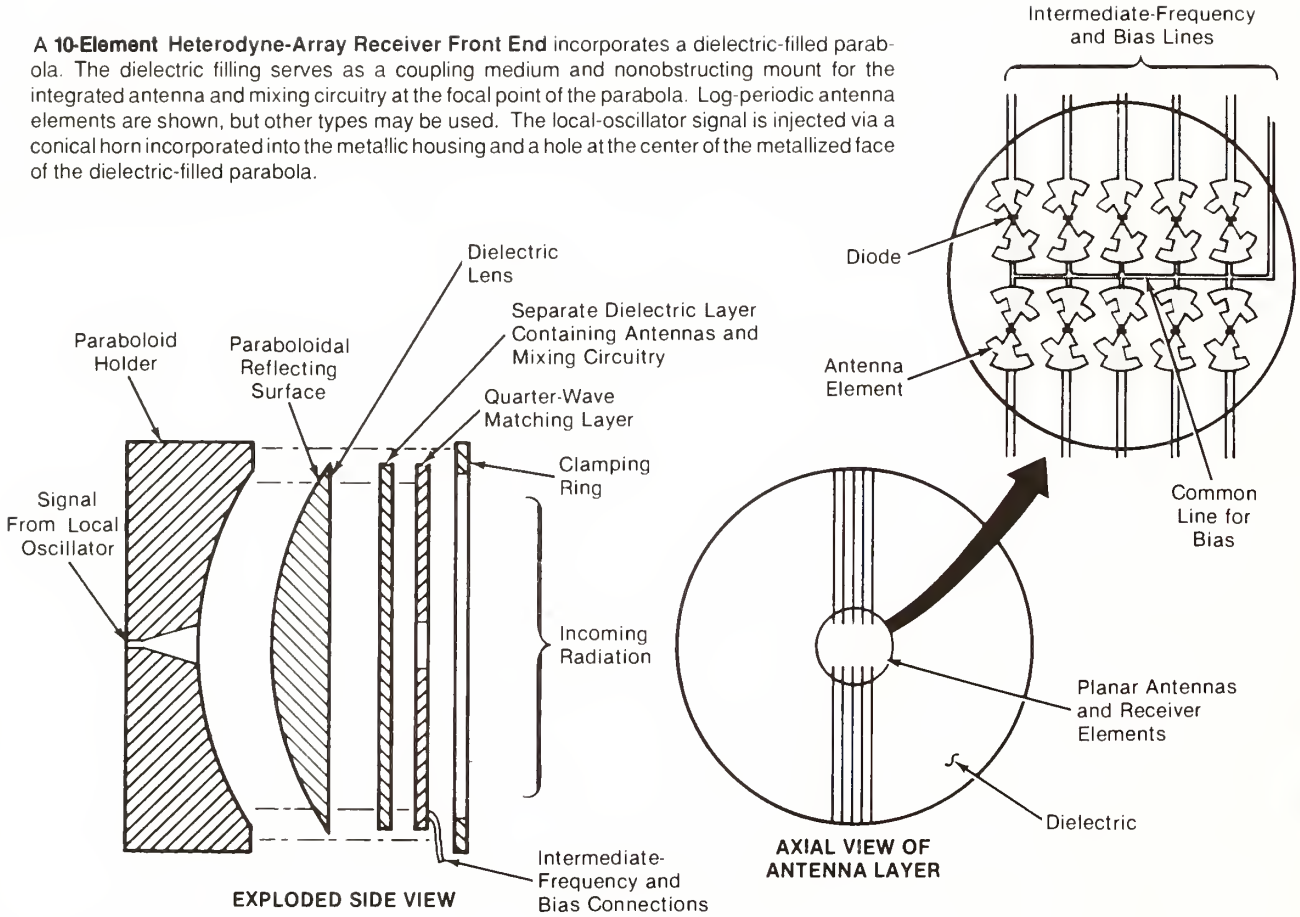
The f/D ratio of the input or output beam can be adjusted by forming the planar surface of the lens slightly inside or outside the nominal focal point.

Since off-axis rays entering the dielectric come to a focus on the flat surface of the lens but laterally displaced from the focal point, the dielectric-filled parabola can be used with a planar array. In fact, due to the refraction, which occurs at the dielectric/air interface, beam steering to greater angles off axis is possible than with an equivalent air-filled paraboloidal system.

The dielectric-filled parabola can be used over a wide range of frequencies and in a variety of modes: as a receiver or transmitter, in a heterodyne or direct-detection mode, with a single element, or with an array. It combines the high directivity of a parabolic reflector with the convenience of a large substrate lens on which both planar antenna elements and receiving or transmitting devices can be integrated. It allows some control over the output beam and can match very-broad-beamed radiators to systems that have reasonable f/D ratios. The design is inherently robust, is easy to fabricate, can be scaled to very high frequencies, and is cryogenically coolable.

Although intended for use in the millimeter- and submillimeter-wavelength bands, operation at lower frequencies is possible

A **10-Element Heterodyne-Array Receiver Front End** incorporates a dielectric-filled parabola. The dielectric filling serves as a coupling medium and nonobstructing mount for the integrated antenna and mixing circuitry at the focal point of the parabola. Log-periodic antenna elements are shown, but other types may be used. The local-oscillator signal is injected via a conical horn incorporated into the metallic housing and a hole at the center of the metallized face of the dielectric-filled parabola.



and, for example, at X-band (8 to 12 GHz), an acceptably large parabola would be 8 in. (20 cm) in diameter and 2 in. (5 cm) thick.

This work was done by Peter H. Siegel of Caltech for **NASA's Jet Propulsion Laboratory.** *NPO-17802/TN*

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NASA Tech Brief
National Aeronautics and
Space Administration

Calculating Performances of Fabry-Perot Etalons

Effects of changes in design can be determined quickly.

Fabry-Perot etalons are optical filters used to select wavelengths in lasers, radiometers, and other electro-optical devices. The Etalon Model computer program implements a stand-alone mathematical model of an etalon. It is designed to perform calculations over many wavelengths. The model can be used to determine the sensitivity of a filter to changes in temperature, thickness tolerances, or alignment angles of an etalon design. A preprocessor and postprocessor are included to facilitate case studies.

The Etalon Model program calculates several performance parameters of etalons by use of equations in closed form. It calculates the transmission as a function of wavelength and uses the transmission data to determine additional performance parameters. The calculations are done for two etalons. The first etalon, which is the collimated, untilted etalon, is considered to be placed in a collimated optical beam with the beam at normal incidence; the second etalon, which is the uncollimated, tilted etalon, is considered to be placed in a converging beam at nonnormal incidence. The program is intended to be used for comparison of measurements of an etalon in a collimated beam with the performance of the etalon in an alternative system. The program calculates the parameters for multiple passes through the etalon.

The Etalon Model program was developed on an IBM PS/2 Model 80-071 computer using the Microsoft version 4.01 FORTRAN compiler. It has been implemented under DOS 3.21 and has a memory requirement of 167K. The Etalon Model program was developed in 1988.

This program was written by Patricia L. Cross and Clayton H. Bair of **Langley Research Center.** *LAR-14055/TN*

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NASA Tech Brief
National Aeronautics and
Space Administration

Directional Couplers for Detecting Circular Waveguide Modes

Samples of TE_{11} and TE_{12} modes are coupled selectively out of a circular waveguide.

A report presents additional details of the theory, construction, and measured operating characteristics of the directional couplers described briefly in "Microwave Transmitter With Multimode Output Section" (NPO-16826), *NASA Tech Briefs*, Vol. 12, No. 5 (May 1988), page 22. To recapitulate from the noted article: The directional couplers consist of tapered rectangular-cross-section waveguides fastened lengthwise to the outside of a circular waveguide, with uniformly-lengthwise-spaced round coupling holes between each rectangular waveguide and the circular waveguide. The directional couplers are used to take small samples of the power propagating in the TE_{11} and TE_{12} modes in the circular waveguide from a proposed 400-kW, 34.5-GHz gyroklystron amplifier. The samples of forward- and reverse-propagating powers in these modes are used to diagnose the performance of the amplifier and the associated waveguide components.

The design of the couplers is based on S. E. Miller's theory of loose coupling, which was published in 1954. The sample powers are coupled through the holes via the longitudinal magnetic field in the circular and rectangular waveguides. The sizes of the holes determine the amount of coupling. Each coupler waveguide is attached to the circular waveguide on the short side of its rectangular cross section to prevent the coupling of any transverse magnetic (TM) power out of the circular waveguide.

The coupling to a particular mode in the circular waveguide is maximized by choosing the long side of the rectangular cross section so that the phase velocity of the dominant mode in the rectangular waveguide matches that of the circular-waveguide mode of interest. The holes are spaced lengthwise one-fourth the wavelength of this mode to assure high directivity. Away from the portion of its length that contains the coupling holes, the rectangular waveguide tapers down to a standard size for connection to a detector.

This coupling scheme rejects power propagating in modes other than the mode for which the coupler is designed as well as power propagating in the reverse direction in all modes. The degree of rejection is called the "selectivity." The selectivity for specified modes can be optimized by using a large number of coupling holes and tapering the sizes of the holes as a function of the longitudinal position. A simple computer program takes all of these effects into account, adding the contribution from each coupling hole to yield a figure for the total coupling for each circular-waveguide mode of interest.

The report describes the designs of the TE_{11} and TE_{12} couplers and measurements of their performances. With few exceptions, the measured coupling ratios and selectivities agreed well with those predicted for the designs.

This work was done by Daniel J. Hoppe of Caltech for **NASA's Jet Propulsion Laboratory**. *"Directional Couplers for Detecting the TE_{11} and TE_{12} Circular Waveguide Modes."*
NPO-17175/TN

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NASA Tech Brief
National Aeronautics and
Space Administration

Effects of Dose Rates on Radiation Damage in CMOS Parts

Damage is more severe at lower dose rates.

A report describes measurements of the effects of ionizing-radiation dose rate on the consequent damage to complementary metal oxide/semiconductor (CMOS) electronic devices. This topic is important to the semiconductor industry because the effects of varying dose rates on damage and/or annealing (gradual post-irradiation changes) may have to be taken into account when analyzing test results on device radiation-damage sensitivity. Depending on irradiation time and degree of annealing, the survivability of devices in outer space, or after explosion of nuclear weapons, may be enhanced. However, annealing that involves recovery beyond the pre-irradiation conditions (rebound) may be detrimental.

The test devices were commercial versions of the 4011 quad two-input NAND gate and the 4013 dual "D" flip-flop. These devices were exposed to radiation from Co^{60} and Cs^{137} sources, at various rates from 0.02 to 200 rad (Si)/s. Each exposure was continued until the device was deemed to fail by virtue of changes in quiescent currents beyond manufacturers' specified limits, incorrect outputs, or threshold potentials in excess of 0.45 V.

Experiments were also conducted to study the effects on devices following irradiation, while maintaining the devices under bias. Data were acquired during post-irradiation periods up to 2,231 hours. The annealing responses at increased temperatures (accelerated annealing) of some devices were also measured, to determine whether this was a viable way to shorten the time required to measure post-irradiation effects and reduce testing costs.

Test results led to the discovery that more damage is done at low dose rates than at high, contrary to the previously accepted assumption. One practical implication is that CMOS devices rated by extrapolation of tests at high dose rates, but used in low-radiation environments, may fail two to six times as fast as anticipated. Other conclusions drawn from the tests include the following:

- Rebound occurs in devices exposed at higher rates of dosage but not in those exposed at lower rates.
- The mechanisms of damage at high and low dose rates appear to be different.
- Accelerated annealing is acceptable for the study of postirradiation effects.

This work was done by Charles A. Goben, James R. Coss, and William E. Price of Caltech for **NASA's Jet Propulsion Laboratory**. *"Dose Rate Dependence of Failure Levels and Post Irradiation Effects (PIE) of Commercial CMOS 4000 Series Parts."*
NPO-17344/TN

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NASA Tech Brief
National Aeronautics and Space Administration
Lewis Research Center, Cleveland, Ohio

High-Efficiency Klystron for Television Transmitters

A multistage depressed collector recycles energy from spent electrons.

An improved klystron is designed for use as the final amplifier in an ultrahigh-frequency (UHF) television transmitter. The new device incorporates a multistage depressed collector (MSDC) of advanced design to increase efficiency by recovering, from the spent electron beam, some of the residual kinetic energy that would otherwise be dissipated as heat. Originally developed by NASA to increase the efficiencies of spaceborne transmitters, the MSDC technology can halve the power consumed by a typical UHF television transmitter. The MSDC-klystron concept could also be applied to increase the efficiencies of microwave communication, equipment, radar systems, and particle-beam accelerators.

The experimental version of the MSDC klystron was made by modifying a commercial klystron that has five internal cavities and provides 60 kW of power at frequencies from 700 to 850 MHz (see Figure 1). The collector is enclosed in a metal shield to minimize radio-frequency interference. It is composed of five elements mounted between electrically insulating ceramic rings. Each electrode contains a passage for cooling water. A refocusing electromagnet inserted between the klystron and the collector adjusts the electron beam as it enters the collector.

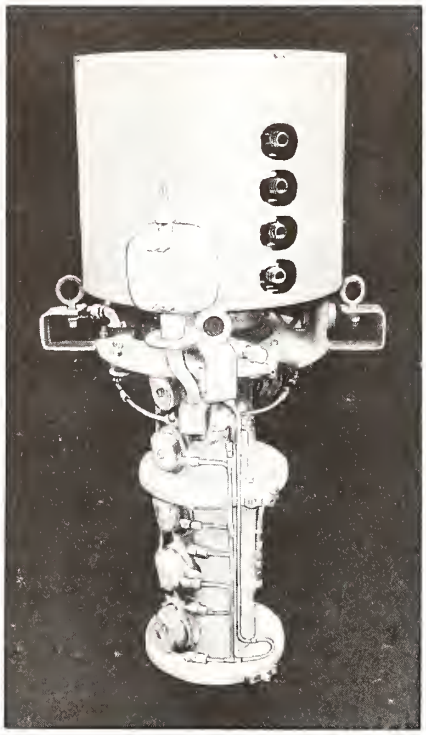

Figure 1. The **Multistage Depressed Collector** at the top of the klystron is shown with its metal shield.

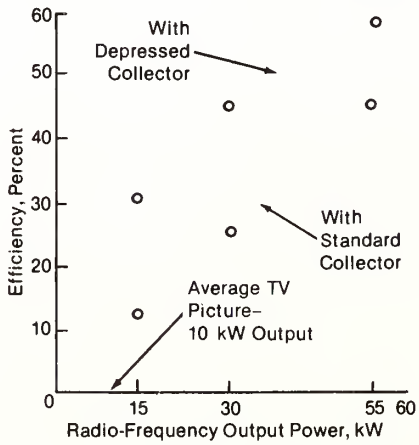

Figure 2. The **Overall Efficiency** of the MSDC klystron is compared with that of the conventional version of the same klystron.

The experimental klystron was tested in a pulsed mode at 60 pulses per second, each pulse lasting 16.7 μs. Its performance was measured over a wide range of operating conditions to obtain a complete characterization. From the measurements, the efficiency was calculated and plotted as a function of radio-frequency output power (see Figure 2). More, recently, another type of UHF television klystron that has four external cavities was modified to an MSDC design. Two such tubes were tested and found to perform similarly to the experimental klystron. In addition one of the tubes performed satisfactorily in a continuous-wave mode under simulated television conditions.

In comparison with a typical klystron now in use in UHF television stations, the new klystron can save as much as 400,000 kWh per year. In terms of typical prices for electricity in 1989, this amounts to an annual saving of about $30,000.

This work was done by Peter Ramins and James Dayton of Lewis Research Center, and Earl McCune, Sr., of Varian Associates, Inc., and Henry Kosmahl of Analex for **Lewis Research Center.**
LEW-14926/TN

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NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Licensing Opportunity

MCT/MOSFET Switch

A hybrid of two different switching transistors has large safe operating area and high speed.

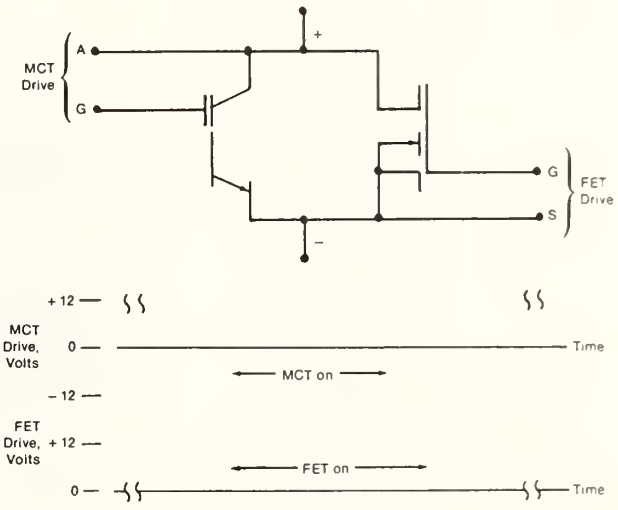
A metal-oxide/semiconductor-controlled thyristor (MCT) and a metal-oxide/semiconductor field-effect transistor (MOSFET) have been connected in a switching circuit to obtain better performance than is possible with either device alone. In comparison with previous semiconductor switching devices and circuits, this combination offers (1) high utilization of silicon (that is, high current per unit total area of silicon), (2) low forward voltage drop during the "on" period of the operating cycle, (3) fast turn-on and turnoff, and (4) large turnoff safe operating area (a safe operating area on a plot of operating voltage vs. current vs. time, characterized by a high current density and the ability to turn off at high voltage).

The advantages of MCT's include high utilization of silicon, the ability to operate at high temperatures, high static blocking voltage, and ease of drive. However, these devices have two major disadvantages: turnoff times are long (of the order of 1 μs), and the maximum voltage that a typical MCT can block during turnoff without the use of a snubber (a resistor-and-capacitor damper) is only half the static blocking voltage. The latter disadvantage necessitates some form of turnoff snubbing; this, in turn, entails additional mass, volume, cost, and loss of power.

In the hybrid switching circuit, the MOSFET is connected in parallel with the MCT. Both the MCT and the MOSFET are driven on at the same time, but the on-state MOSFET drive is continued for a short time after the MCT drive is switched to the off state (see figure). By this scheme, the MCT is made to dominate the behavior of the switch during the on period, whereas the MOSFET is made to dominate the switching action during the turnoff transient.

The total silicon area required in a switching device or combination of devices to keep the forward voltage drop below a given value is considerably less in the MCT/MOSFET combination than in a MOSFET acting alone; that is, much of the high utilization of silicon that characterizes the MCT is preserved. The turnoff switching loss of the combination is only slightly greater than that of a MOSFET acting alone. The turnoff safe operating area of the combination includes both the static-breakdown voltage and the peak allowed current of the MCT; that is, no voltage derating is required to accommodate the dynamics of the MCT.

The optimal ratio between the silicon areas of the MOSFET and the MCT is about 1. The optimal extension of the MOSFET on period is of the order of 3 times the decay time constant of the MCT current. Tests indicate that turnoff switching speed can be increased to about 10 times that of an MCT acting alone, while the utilization of silicon can be increased to about 5 times that of a MOSFET acting alone.



The **Parallel Combination of an MCT and a MOSFET** in a switching circuit combines the advantages of both devices. The MCT dominates the operation during the on-period; the MOSFET dominates during the turnoff transient.

This work was done by Wally E. Rippel of Caltech for **NASA's Jet Propulsion Laboratory**.

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, NASA Resident Office-JPL. Refer to NPO-18001/TN.

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NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Licensing Opportunity

Millimeter-Wave Quantum-Well Frequency Multipliers

A double-barrier quantum-well GaAs diode produced 0.25 mW output at the third harmonic, 191 GHz.

A double-barrier quantum-well GaAs diode achieved 0.61 percent efficiency as a frequency tripler when operated at an input frequency of 63.7 GHz, nearly one-tenth the cutoff frequency of the diode. Efficiency increased with drive level up to the maximum input power available, 40 mW. Inasmuch as this performance is comparable to that of a GaAs varactor diode of the same cutoff frequency, these initial results are considered quite promising.

The diodes are being studied for use in local-oscillator chains in microwave radiometers. Other potential applications include spectrometers and radar.

The various semiconductor devices that could be used as frequency multipliers have different efficiency limitations. There are two types of semiconductor devices with monotonically increasing current-vs.-voltage (I–V) curves: resistive devices (varistors), which have a maximum efficiency of $1/n^2$ for harmonic n, and reactive devices (varactors), which are limited in efficiency by parasitics.

The layered structure of a quantum-well diode is shown in Figure 1. For testing, a diode chip was mounted in a waveguide assembly that had been constructed for testing a varactor frequency tripler. Each 0.1-mm square diode chip has a 10×10 array of the individual 4-μm. diameter diodes. A low-pass filter of suspended stripline on a quartz substrate connected the input waveguide to the quantum-well diode. This structure prevented harmonics from leaking back into the input circuit. The diode chip was indium-soldered to the last low-impedance section of the filter and protruded 0.1 mm into the output waveguide, where a pointed metal whisker 6 μm in diameter made contact with one of the diodes in the array. The whisker acted as an electric-field probe to couple the output to the waveguide.

A double-barrier quantum-well device has two polarity-symmetric negative-resistance regions (see Figure 2). Critical to the achievement of the negative-resistance regions is the structure formed by the thin undoped barriers. These partially transparent reflectors form a Fabry-Perot etalon. This results in a current singularity as the magnitude of the applied voltage increases, followed by a decrease in current above electron-energy resonance. The resulting negative-slope portions of the I–V curve are the negative-resistance regions. Because this curve is not a monotonically increasing function, the $1/n^2$ efficiency limit of varistors does not apply. Because of the symmetry of the response function, only odd harmonics are generated when such a diode is driven by a sinusoidal voltage. This allows the embedding circuit to be substantially less complex than those necessary for previous semiconductors.

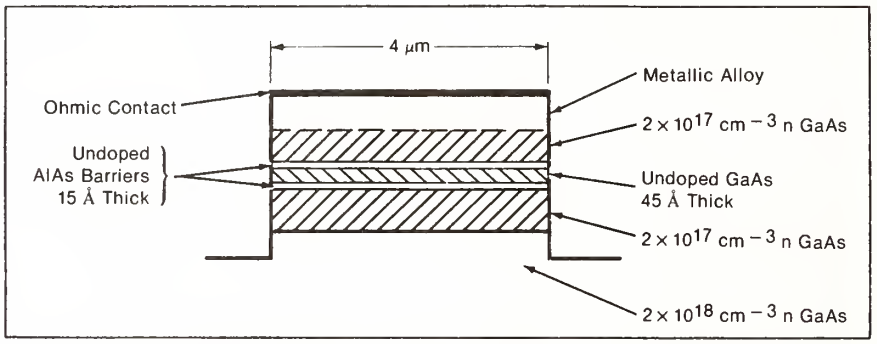
4 μm
Metallic Alloy
Ohmic Contact
2 × 10^17 cm^−3 n GaAs
Undoped AlAs Barriers 15 Å Thick
Undoped GaAs 45 Å Thick
2 × 10^17 cm^−3 n GaAs
2 × 10^18 cm^−3 n GaAs

Figure 1. **Quantum-Well Double-Barrier Diodes** were fabricated on a GaAs chip. Each diode was a mesa-shaped structure 4 μm in diameter. The electrical parameters of each diodes were series resistance = 15 Ω, capacitance = 15 fF, and cutoff frequency = 730 GHz.

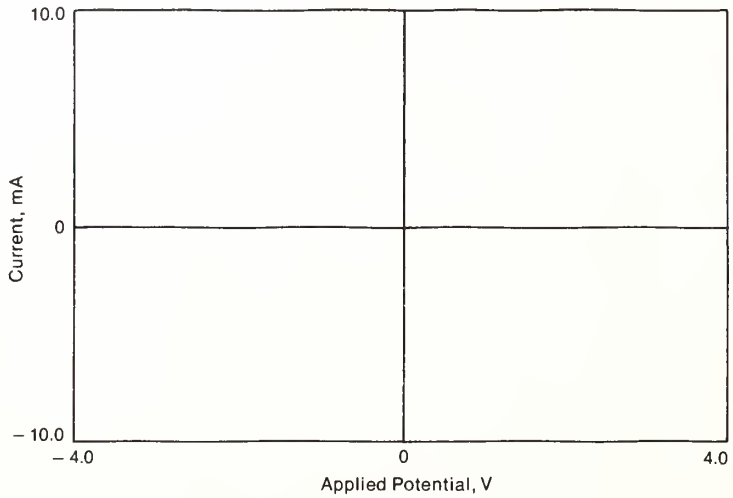

Figure 2. The **I–V Curve** of the quantum-well diode is essentially symmetric about the origin and has two negative-resistance regions.

This work was done by Paul D. Batelaan and Margaret A. Frerking of Caltech for **NASA's Jet Propulsion Laboratory.** *NPO-17584/TN*

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NASA Tech Brief
National Aeronautics and Space Administration

More About Lens Antenna for Mobile/Satellite Communication

Details of a flat phased-array design are presented.

A report presents additional details of the design of the proposed phased-array antenna described in "Lens Antenna for Mobile/Satellite Communication" (NPO-16948), *NASA Tech Briefs*, Vol. 12, No. 10 (November, 1988), page 24. The antenna is intended to be compact and to lie flat on top of a vehicle on the ground. The antenna would transmit and receive circularly polarized radiation in the frequency ranges of 821 to 825 MHz and 860 to 870 MHz, respectively (or at other frequencies by suitable scaling of its dimensions). The transmitting and receiving beams would be electronically steerable to any of 48 evenly spaced directions to provide complete azimuth coverage, and would be fixed, but wide, in elevation, to provide coverage at elevation angles from 20° to 60°.

The report tells how the design evolved, motivated by the need for an electronically steerable vehicle antenna of relatively low cost. The design was simplified (and, consequently, the cost was reduced) somewhat by incorporating the fixed-elevation feature. In a standard approach to the design of an electronically steerable antenna, a phase shifter is required for each radiating element. To reduce the number of phase shifters and, thereby, the cost, another feeding technique must be used. The report discusses feeding networks that consist of various combinations of more or fewer phase shifters, hybrid couplers, interconnecting cables, striplines, and dielectric lenses. It discusses the design features of each as they pertain to the intended mobile/satellite application, showing why each prior feeding arrangement was rejected in favor of the R-KR-lens-fed array that was ultimately selected for the proposed design.

As described in the noted previous article in *NASA Tech Briefs*, an R-KR lens is a stripline disk of radius KR ($K < 1$), through which radiating elements, evenly spaced on a circle of radius R, are fed. The lens is fed from the point on its periphery that is opposite that of the intended beam azimuth. The lens eliminates the need for a phase shifter for each radiating element by providing all the necessary phase shifting between the feed point and the radiating elements.

To obtain complete illumination of the aperture, the design of the specific lens calls for two pairs of stripline lens layers (lens A and lens B), a central radiating element plus two concentric rings of radiating elements, and power-dividing and -switching networks. By use of three different schemes for apportioning the power fed to the ports of lenses A and B, and by switching among the 24 azimuthally spaced ports, the beam would be steered to the desired one of the 48 azimuthal headings.

The report describes computer simulations of the far-field radiation pattern of the antenna. The results of the simulation were used to assess the performance and were fed back into the design to obtain dimensions that would optimize coverage. Diffraction from the edges of the roof of the vehicle was also considered, inasmuch as it could affect communication with a satellite near the horizon. Also investigated were the projected ability of the antenna to separate signals to or from two satellites located at different longitudes, and considerations involved in the design of an acquisition-and-tracking system that would include the antenna.

This work was done by Y. Rahmat-Samii of Caltech and D.G. Bodnar and B.K. Rainer of Georgia Institute of Technology for **NASA's Jet Propulsion Laboratory**. *"A Novel Array Antenna for MSAT Applications."* *NPO-17680/TN*

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NASA Tech Brief
National Aeronautics and
Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

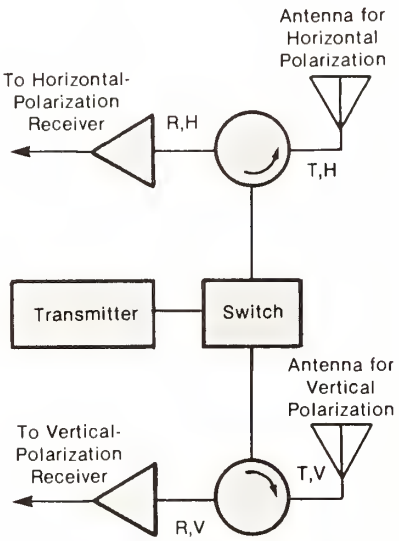
Phase Calibration of Radar Polarimetric Data

Calibration parameters are extracted from the data themselves.

A technique for the phase calibration of data acquired by an airborne imaging radar polarimeter is based on the extraction of the calibration parameters from the data themselves. It is not necessary to place calibration equipment on the ground or to have prior knowledge of conditions on the ground. The new phase-calibration technique enables the use of a data-compression technique to reduce the volume of data in a synthetic-aperture-radar correlator.

The phases of the radar return signals are essential elements of the radar polarimetric data. Therefore, phase calibration must be performed to correct for the phase delays along the transmitting and receiving paths of the radar equipment (see figure).

The new technique involves modifications of the Stokes matrices, which are 4×4 matrices, each element of which is a sum of products of elements of the scattering matrix. (The scattering matrix represents, in complex-number form, the relationship between the horizontal and vertical components of the radiation transmitted to, and returned from, the portion of the target in the designated picture element.) The first step is to compute the average, over all picture elements, of the phase difference contained in the cross-polarization terms of the receiving matrix, and to store this phase difference in a header that accompanies the full set of data. The step is to symmetrize the receiving matrix, which is similar to the scattering matrix except that it includes the unknown phase delays for which corrections have to be made. This symmetrization avoids the duplication of cross-polarization terms. These two steps reduce the volume of data.



A **Typical Radar Polarimeter** includes transmitting (T) and receiving (R) channels for horizontally (H) and vertically (V) polarized signals. The phase delay in each channel is usually known only approximately if at all. Consequently, it is necessary to phase-calibrate the radar return signals.

The symmetrized version of the receiving matrix is converted into Stokes-matrix format. The Stokes matrices can be averaged spatially to reduce the volume of data. In this case, the data are compressed further by quantization of the elements of the Stokes matrices. In the original application, the volume of data was reduced from 128 Mbytes to 10 Mbytes for each set.

The particular combination of phase-calibration and data-compression techniques enables any amount of averaging to reduce the volume of data (at the expense of resolution), without loss of the fidelity of phase calibration. The phase-calibration algorithm is reversible in that if the data are phase-calibrated incorrectly, they can be recalibrated.

This work was done by Howard A. Zebker and Yunling Lou of Caltech for **NASA's Jet Propulsion Laboratory.**
NPO-17844/TN

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
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NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Licensing Opportunity

Planar Microstrip Yagi Antennas

Mutual coupling between microstrip elements, ordinarily considered a nuisance, is used to advantage.

A developmental class of antennas is based on the combination of the microstrip-patch and Yagi-array concepts. Heretofore, mutual coupling between microstrip antenna elements has usually been considered a disadvantage because in many cases it has reduced gains while increasing side lobes of radiation patterns. In the new Yagi microstrip antennas, as in Yagi's original linear arrays of rod elements, the microstrip elements are designed to exploit mutual coupling in a way that shapes the radiation pattern to advantage. Potential applications include antennas on land vehicles, television receiving antennas, and conformal antennas on aircraft.

The microstrip Yagi concept is applicable to both linearly and circularly polarized antennas. Figure 1 illustrates the general configuration of a four-element microstrip Yagi antenna with one driven element, one reflecting element, and two directing elements. Such an antenna could also serve as part of an array. Although such an antenna or array tends to be larger than is a conventional microstrip antenna or array, its use of fewer driven elements results in less complexity and reduced loss of power in the associated transmission lines and other coupling and power-distributing circuitry.

Figure 2 illustrates the kind of improvement that can be obtained by adding Yagi parasitic elements to a microstrip array to change a radiation pattern. When the reflector and directors are added, the direction of peak gain is tilted away from broadside, toward the end-fire direction (the direction along the centerline of the patches in the microstrip plane).

The dimensions of the Yagi microstrip elements and the distances between them can be optimized for a particular purpose by trial and error or chosen on the basis of principles similar to those used to design conventional rod-dipole Yagi antennas. However, some aspects of the design problem are unique to microstrips. In particular, the dielectric constant should not be less than about 1.5 or greater than about 5. If it is too low, the microstrip patches have to be made so large that the required separations between the centers of patches cannot be maintained; if it is too high, the patches have to be made so small that the gaps between them become large enough to substantially reduce mutual coupling. In general, the separations between the centers and the sizes of parasitic patches govern phases, while gaps between parasitic patches govern amplitudes.

This work was done by John Huang of Caltech for **NASA's Jet Propulsion Laboratory.**

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, NASA Resident Office-JPL. Refer to NPO-17873/TN.

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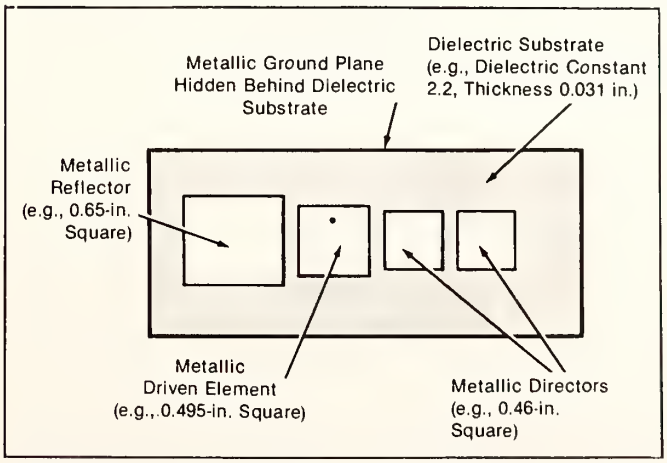
Metallic Ground Plane Hidden Behind Dielectric Substrate
Dielectric Substrate (e.g., Dielectric Constant 2.2, Thickness 0.031 in.)
Metallic Reflector (e.g., 0.65-in. Square)
Metallic Driven Element (e.g., 0.495-in. Square)
Metallic Directors (e.g., 0.46-in. Square)

Figure 1. A **Microstrip Yagi Antenna**, like a conventional rod-dipole Yagi antenna, includes a driven radiating element and parasitic (reflecting and directing) radiating elements. The numerical specifications shown for example are those of an experimental antenna designed for operation at a frequency of 6.9 GHz.

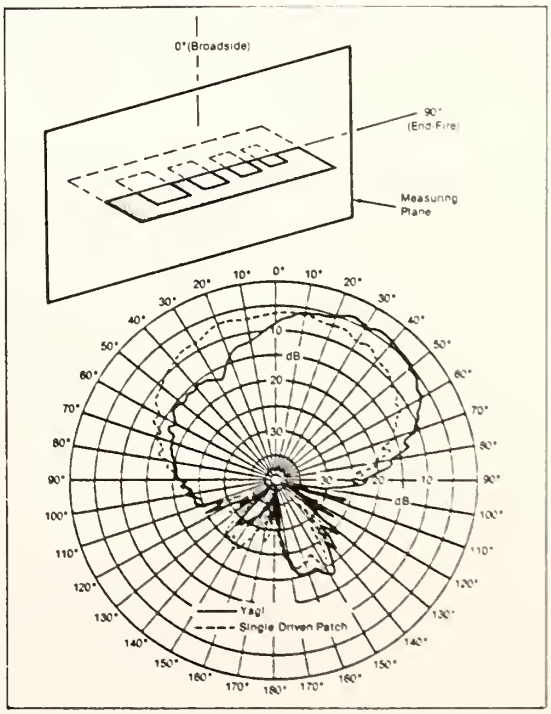

Figure 2. The **Radiation Pattern** of the experimental 6.9-GHz, linearly polarized microstrip Yagi antenna described in Figure 1, is compared with that of a similar antenna that includes only the driven element. On the circular chart, 0° denotes the broadside direction in the measuring plane.

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NASA Tech Brief
National Aeronautics and Space Administration
Lewis Research Center, Cleveland, Ohio

Licensing Opportunity

Real-Time Digital Compression of Television Image Data

Broadcast-quality images can be transmitted at low data rates.

A digital encoding/decoding system compresses color television image data in real time for transmission at lower data rates and, consequently, lower bandwidths. The reconstructed images are of broadcast quality — indistinguishable from those produced by the video source signal. A prototype of the system has been built from transistor/transistor logic digital devices, first-in/first-out memories, programmable read-only memories, and random-access memories.

The system implements a predictive coding process, in which each picture element (pixel) is predicted from the values of prior neighboring pixels, and the coded transmission expresses the difference between the actual and predicted current values. The system combines a differential pulse-code modulation process with a nonlinear, nonadaptive predictor, a nonuniform quantizer, and a multilevel Huffman encoder. (Huffman coding assigns shorter code words to the quantized levels that have greater probability of occurrence: the result is an overall reduction in the required rate of transmission.)

Digital encoding and decoding of video images has historically involved engineering compromises among the quality of the reconstructed images, data-compression performance, and complexity of equipment. The new system achieves better performance (better quality of image at comparable rates of transmission) than do prior transform or interframe coding systems, yet the equipment is less complicated.

The incorporation of the nonadaptive predictor and the multileveled Huffman coder sets this system apart from older predictive systems. The nonadaptive predictor improves the reconstructed image by providing more rapid convergence at transition points in the image, thereby improving edge-detection performance. The use of the multilevel (as distinguished from single-level) Huffman codes further reduces the number of bits per pixel by enabling nearly all pixels to be represented by short code words. A separate Huffman code set is generated for each quantization level on the basis of previously determined statistical properties of "typical" pictures. These statistics indicate a trend for neighboring pixels to fall into the same or nearly the same quantization levels. The multilevel Huffman code takes advantage of this trend to obtain additional compression of data.

The multilevel Huffman coding scheme improves digital encoding/decoding system performance by an average of 2 bits per pixel over that of standard differential pulse-code modulation, and by 0.5 bits per pixel over standard differential pulse-code modulation with a single-level Huffman code. Overall, the new system processes standard broadcast color television signals in real time at the average rate of 1.8 bits per pixel, as compared with 3 to 4 bits per pixel in older predictive systems.

This work was done by Scott P. Barnes, Mary Jo Schalkhauser, and Wayne A. Whyte, Jr., of **Lewis Research Center.**

This is the invention of a NASA employee, and a patent application has been filed. Inquiries concerning license for its commercial development may be addressed to the inventor, Wayne A. Whyte.
LEW-14945/TN

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NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Starting Circuit for Erasable Programmable Logic Device

The voltage regulator is bypassed to supply the starting current.

A starting or "pullup" circuit supplies the large inrush of current required by an erasable programmable logic device (EPLD) while it is being turned on. The starting circuit operates only during such intervals of high demand for current and has little effect at any other time.

An EPLD is an integrated circuit in which cells erasable by ultraviolet radiation are used to configure elements that perform logical functions. Typically, an EPLD is intended to operate from a regulated 5-Vdc power supply, drawing about 3 rnA when at full power with a slow (100 kHz) clock. This low power is an advantage where power must be supplied by a battery.

Because of certain voltage-dependent design features in the portion of the EPLD circuitry that affects the current drawn in the operating mode, the EPLD draws a relatively high current when the supply voltage, V_{CC}, is first turned on. This current rises to a peak of about 40 mA as V_{CC} rises to 3 V. As V_{CC} goes higher, the current abruptly drops to the full operating level. If V_{CC} subsequently falls below 2.5 V, the device abruptly returns to the high-current mode (see Figure 1).

The 40-mA peak starting current is more than can be supplied by a typical voltage regulator designed for operation with low-power circuitry. Therefore, if no provision were made to bypass the voltage regulator during startup, the EPLD would continue to draw the maximum current that the regulator could supply, and V_{CC} could not be made to reach or exceed 3 V.

The starting circuit (see Figure 2) performs the needed bypass, acting as a current-dependent shunt that connects the battery or other source of power more nearly directly to the EPLD. The resistor in the starting circuit is chosen so that the voltage across it is 0.6 V when the current through it (which nearly equals the load current) is 80 percent of the maximum rated current of the voltage regulator. As long as the current is less than this value, the transistor remains turned off and effectively out of the circuit. When the current exceeds this value, the transistor turns on, diverting current around the voltage regulator.

It is also noteworthy that the input capacitor of the regulator is removed when the starting circuit is installed. This is done to protect the transistor. The battery can supply a large current, but not as much as can a capacitor during a momentary surge. Thus, the deletion of the capacitor reduces the probability of damage to the transistor in the event of a short circuit in or across the load.

This work was done by Steven W. Cole of Caltech for **NASA's Jet Propulsion Laboratory.** *NPO-17827/TN*

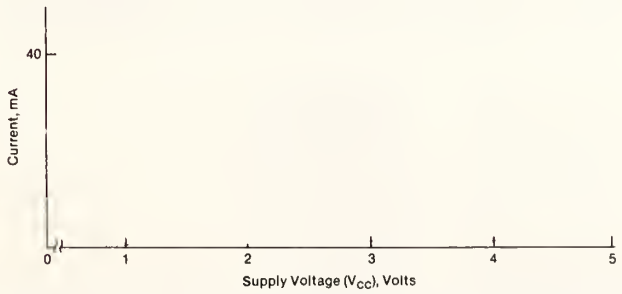

Figure 1. The **Current vs Supply Voltage** of a typical EPLD includes a partly hysteretic high-current, low-voltage regime.

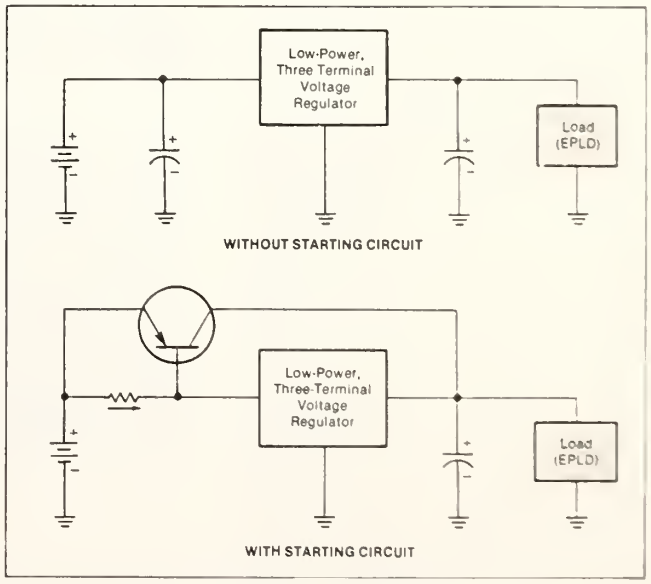

Figure 2. The **Starting Circuit** shunts current around the voltage regulator during the initial rise in V_{cc} to pull the EPLD out of the low-voltage, high-current regime.

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NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Licensing Opportunity

Self-Aligned Guard Rings for Schottky-Barrier Diodes

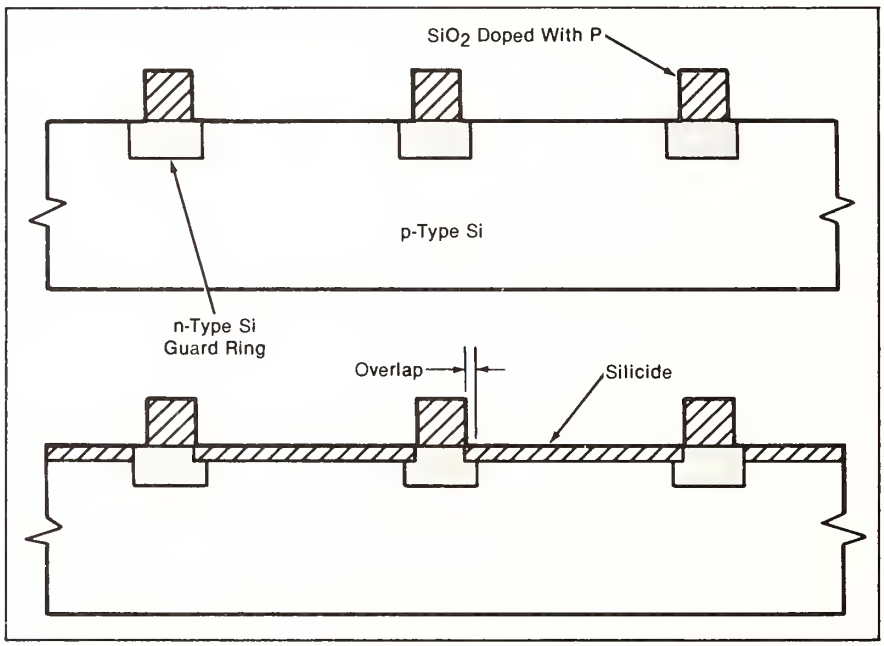
The active area would be increased.

A proposed self-aligned guard ring would increase the active area of a Schottky-barrier infrared detector. The self-alignment concept was developed for silicide Schottky-barrier diodes in which platinum silicide or iridium silicide Schottky-contacts provide cutoff wavelengths of about 6 or 10 μm, respectively.

Silicide diodes have been built into focal plane arrays of 512 by 512 elements for infrared imaging. Usually, each diode element must be surrounded and overlapped by an n-type guard ring to disperse electric-field lines at the edge of the silicide layer in order to suppress the leakage current.

Self-alignment eliminates the need for much of the overlap between the guard ring and the silicide contact. Ordinarily, an overlap of 2 μm is necessary to allow for misalignment of the ring mask and lateral diffusion and straggling of dopant ions during the fabrication of the guard rings. In a diode of 30 by 48 μm, for example, the overlap reduces the effective area by about 20 percent. Inasmuch as the overlap area is not sensitive to infrared, the result is a significant loss of output.

To begin the fabrication of a self-aligned array of diodes, a layer of silicon dioxide doped with phosphorus would be deposited on a silicon substrate. This layer would be etched to form a grid defining the elements of the array (see figure). The phosphorus in the grid would be diffused into the silicon to form a grid of n-type guard rings. Thus, self-alignment would make fabrication simpler by eliminating the masking step for diffusion of the n-type guard ring. Finally, the desired metal would be deposited on the exposed silicon surface, and the silicide layer would be formed by annealing. The only overlap of a guard ring with the silicide layer of a cell would be that caused by sideways diffusion of the phosphorus, which can be kept quite low by adjusting the time and temperature of the diffusion process.



A **Grid of Silicon Dioxide Doped With Phosphorus** would be etched on a silicon wafer, and phosphorus from the grid would diffuse into the substrate (top), creating n-type guard rings. Silicide layers would be formed in the open areas of the grid (bottom). The overlap of the guard rings and the silicide layers would be small.

This work was done by True-Lon Lin of Caltech for **NASA's Jet Propulsion Laboratory.**

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA's Resident Office-JPL. Refer to NPO-17734/TN.

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NASA Tech Brief
National Aeronautics and Space Administration
John F. Kennedy Space Center, Florida

Licensing Opportunity

Switching Matrix for Optical Signals

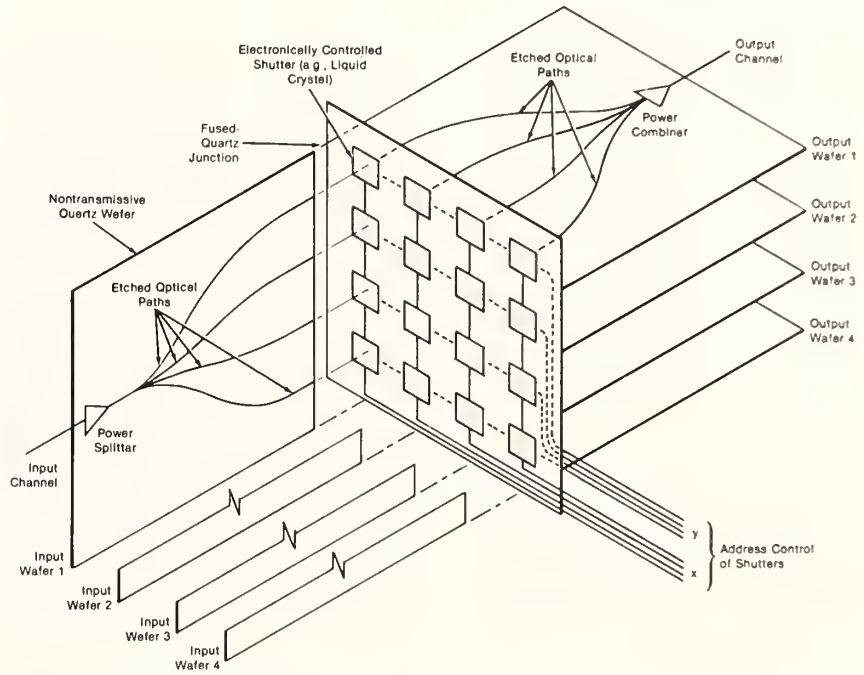
Size, weight, and power consumption would be reduced.

A proposed matrix of electronically controlled shutters would switch signals in optical fibers between multiple input and output channels. The device would serve as a building block for small, low-power, broadband television- and data-signal-switching systems that provide high isolation between nominally disconnected channels. In principle, any degree of isolation between input and output channels could be achieved by stacking a sufficient number of such devices back-to-back in a package.

Present switching devices incorporate mechanical coaxial or reed relays or semiconductor matrices of moderate to large size, weight, and power consumption. The proposed device offers the advantages of microscopic integrated-circuit design, power consumption in the range of microwatts to milliwatts, bandwidth as high as 30 GHz, and separation of input and output power sources. The switching speed is limited only by the characteristics of the liquid crystal, electro-optical cell, or other type of electronic shutter.

The figure shows a representative device of four input and four output channels. The input and output paths would be etched into quartz wafers, which would be fused to a quartz wafer that contains the shutters. Each shutter would be opened or closed by a signal addressed to it according to its row and column (standard "x–y"-address control).

Each input channel would lead to a unique column of the shutters. The power in each input channel would be split optically, with automatic gain control, for distribution among the four input paths leading to the four shutters in its column. By use of a similar configuration, signals would be led to each output channel from a row of shutters. The signals from the shutters in each row would be combined with automatic gain control at the junction of the paths from the shutters, then launched into the output channel.



An **Electronically Controlled Matrix of Shutters** would switch signals from input channels on quartz wafers to output channels on other quartz wafers stacked perpendicularly.

This work was done by Charles H. Grove of **Kennedy Space Center.**

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Kennedy Space Center. Refer to KSC-11392/TN.

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NASA Tech Brief
National Aeronautics and
Space Administration

Diffraction Analysis of Distorted Reflector Antennas

The effects of systematic distortions of surfaces on radiation patterns are predicted.

The increasing use of multiple- and contour-beam satellite and low-sidelobe tracking-radar reflector antennas demands accurate estimates of the sidelobe levels and overall characteristics of patterns in terms of errors of the reflector surfaces. These estimates are important in evaluating the levels of isolation between beams for a noninterfering multiple-beam communication system and for systems with stringent sidelobe requirements.

In predicting the performance of antenna systems, it has been found that far-field patterns can be very different from statistically computed average patterns because of irregularities induced by such factors as gravitation, heat, mechanical movement, and manufacturing irregularities. The computer program for Diffraction Analysis of Reflector Antennas Subject to Systematic Distortions addresses these problems by predicting the performance of reflector antennas subject to sinusoidal, thermal, or gravitational distortions.

Particular attention is given to a situation in which the antenna surface is described only at discrete points. In many cases, the prescribed discrete points do not lie on a regular grid — a condition that typically makes the task of locating them more complex. This program provides a local interpolation algorithm that can be readily applied to a nonregular distribution of data.

The program was developed in UNIVAC FORTRAN 77 for a UNIVAC computer. The IMSL library or similar subroutines are required. Some of the routines were written for use with JPL's Athena FORTRAN compiler (TFOR) and may not compile directly on a standard compiler. Since TFOR is a subset (with minor discrepancies) of FORTRAN 77, it should be a simple task to upgrade the code to FORTRAN 77 standards. Tips for removing UNIVAC-dependent features are included in the update documentation. The program was written in 1985 and updated in 1987.

This program was written by Yahya Rahmat-Samii and Jeffrey H. Mumford of Caltech for **NASA's Jet Propulsion Laboratory.** *NPO-16818/TN*

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
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NASA Tech Brief
National Aeronautics and
Space Administration

Computing Scattering Matrices for Circular Waveguides

This program computes scattering at junctions between sections on a common axis.

Accurate computer modeling of passive circular waveguide components is often required during design for optimization of frequency response and/or determination of the tolerances required of components in order to meet radio-frequency specifications. Many circular waveguide devices can be represented either exactly or approximately as series of circular waveguide sections that have a common axis. In addition, smooth tapers and horns of arbitrary profile can be approximated by series of small steps. The Scattering Matrix Program for Circular Waveguide Junctions computes the scattering matrix for a series of circular waveguide sections. These sections must have the same axis, but the radius and length of each section are completely arbitrary.

Devices that can be analyzed include a simple waveguide step discontinuity like that used in a dual-mode horn, a stepped matching section, or a corrugated waveguide section with constant or varying slot depth. Certain types of corrugated horns can also be analyzed with this program. The mathematical model used in the program accurately predicts the reflection and transmission characteristics of such devices, taking into account the excitation (if it occurs) of modes of higher order as well as multiple reflections and energy stored at each discontinuity.

For a device that is large with respect to a wavelength, in which many modes can propagate, the reflection and transmission properties may be required for a mode of higher order or for a series of modes exciting the device. Such interactions are represented best by defining a scattering matrix for the device. The matrix can be determined by matching modes at each discontinuity. The results for individual discontinuities are then cascaded to obtain the matrix for the entire device.

This program was written in FORTRAN 77 for execution on a UNIVAC 1100 series computer. IMSL subroutines are required. This program was developed in 1987.

This program was written by Daniel J. Hoppe of Caltech for **NASA's Jet Propulsion Laboratory.**
NPO-17245/TN

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Energy

0033 Advanced Combustion System for Industrial Boilers

0034 Fireflies Light the Way to Improve Oil Yields

0035 Solid Oxide Fuel Cell/Hybrids for Transportation

0036 Energy-Efficient Windows and Window Coverings

0037 Copper Chloride Cathode for Liquid-Sodium Cell—Energy density is higher than that of previous liquid-sodium cells. (Licensing Opportunity)

Software

0038 FLAP Structural Dynamics Code

Advanced Combustion System for Industrial Boilers

U.S. consumption of oil presently exceeds reserves by 44 percent. Yet, 33 percent of the U.S. industrial sector is fitted with oil burners. Switching oil burning furnaces to coal usually ended up with severe fouling, slagging, and other deposition in the systems. Development of an advanced coal-combustion system will allow firetube boilers to use dry, ultrafine, cleaned coal as an economical, efficient replacement. Tests, funded by the Pittsburgh Energy Technology Center, are being conducted by the University of Tennessee Space Institute (UTSI) in Tullahoma, Tennessee, on an oil-designed, 200 Hp firetube boiler. The boiler used a very clean, dry ultrafine-grind coal with a topsize of 40 microns, which is about the consistency of flour. The burner-assembly, designed by UTSI, replaces the entire commercial oil/propane burner-assembly. The coal is fed to the burner via a UTSI-designed pneumatic transport system that uses small quantities of conveying gas (one pound of nitrogen per 20 pounds of coal). All combustion tests were conducted without preheating the combustion air. Several other components of the system were also developed. The most important developments were an injector and an automatic control system. The simple and successful ultrafine-coal injector was designed for direct replacement of a standard oil injector. The automatic control system monitors the performance of the assembly and changes parameters in the system in order to maximize productivity under certain conditions. Recent tests in the burner using Eagle Butte, Wyoming, subbituminous coal achieved a 99.9 percent carbon conversion efficiency at full load (6 million Btu/hr) despite the 16.5 percent moisture level of the fuel. The burner fully used the reactive qualities of the coal. Sulfur dioxide emissions were unexpectedly low (less than 0.4 pound per million Btu) due to the reactive nature of the ash.

Laboratory Name: Pittsburgh Energy Technology Center.

Reference No.: DOE/PETC-1.

Patent Status: Not patented.

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Solar Energy Research Institute

Fireflies Light the Way to Improve Oil Yields

The gene that enables a firefly to create small flashes of light has been successfully inserted into a simple green algae. This is a promising first step for SERI researchers as they attempt to genetically engineer microalgae for higher oil yields.

Certain microalgae produce oil that can be processed into high-value transportation fuels such as diesel and gasoline. Researchers plan to obtain higher oil yields on a more reliable basis by combining optimal genes from various species. To be sure that there are no physical or chemical barriers to this process, they first inserted a gene with easy-to-observe results.

The firefly gene was mixed with the green algae *Chlorella*, whose cell walls had been broken down with enzyme. Subsequent extracts of the microalgae emitted light, proving that the firefly gene was both incorporated and active. *Chlorella* also appeared to accept parts of viral and bacterial genes, indicating that its DNA may be compatible with genes from many sources.

However, light emissions from the modified microalgae decreased within a few days. Researchers suspect that the firefly gene may not be passed on to subsequent generations of *Chlorella*. They will attempt to resolve this problem before inserting foreign genes related to oil production.

SERI maintains the nation's only collection of microalgae selected for high growth rates, high oil yields, and high tolerance to adverse conditions. Genetically optimized strains would be ideal for large-scale growth in the saline and brackish waters of the desert Southwest. Microalgae farms in this region could provide the United States with the equivalent of 15% of its annual gasoline consumption while removing large quantities of atmospheric carbon dioxide, the primary greenhouse gas.

To test the feasibility of genetically altering microalgae, SERI researchers inserted a firefly gene into the simple green algae Chlorella.

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Refer to Volume XII, Number 3/TN

Idaho National Engineering Laboratory

Solid Oxide Fuel Cell/Hybrids for Transportation

Fuel cells provide a new and exciting mode of converting hydrogen or hydrocarbon fuels directly into electricity. In particular, the solid oxide fuel cell (SOFC) is an advanced high temperature fuel cell with the following advantages and disadvantages:

A D V A N T A G E S

- Fast electrode kinetics
- High energy densities possible
- External reforming of fuel not required
- High system efficiency
- High grade waste heat available
- CO is a usable fuel
- CO_2 recycling not necessary
- Virtually no harmful air pollution

D I S A D V A N T A G E S

- High cost fabrication using present methods
- High temperatures present sealing and cracking problems
- Relatively high electolyte resistivities

An INEL researcher has been engaged in a program to eliminate or mitigate the above disadvantages by developing new processes to fabricate a planar bi-polar plate type SOFC. Significant progress has been made and fuel cell "stacks" promise to be extremely lightweight with a high energy density suitable for transportation applications (including electric cars). The fuel could be either hydrogen (H_2), methanol (CH_3OH), or liquified natural gas (CH_4).

The SOFC power plant generates DC electricity which could power an electric car or be converted to AC at high efficiencies for home use or input into utility grids. Hybrid designs include combining the SOFC with light-weight, high energy density batteries (such as the Sodium/Sulfur "Beta" battery) or a bottoming cycle (such as the Sodium heat engine). Combined cycle efficiencies could approach 75%, which correspond to hundreds of miles per gallon of fuel in a light-weight vehicle.

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U.S. Navy Fact Sheet

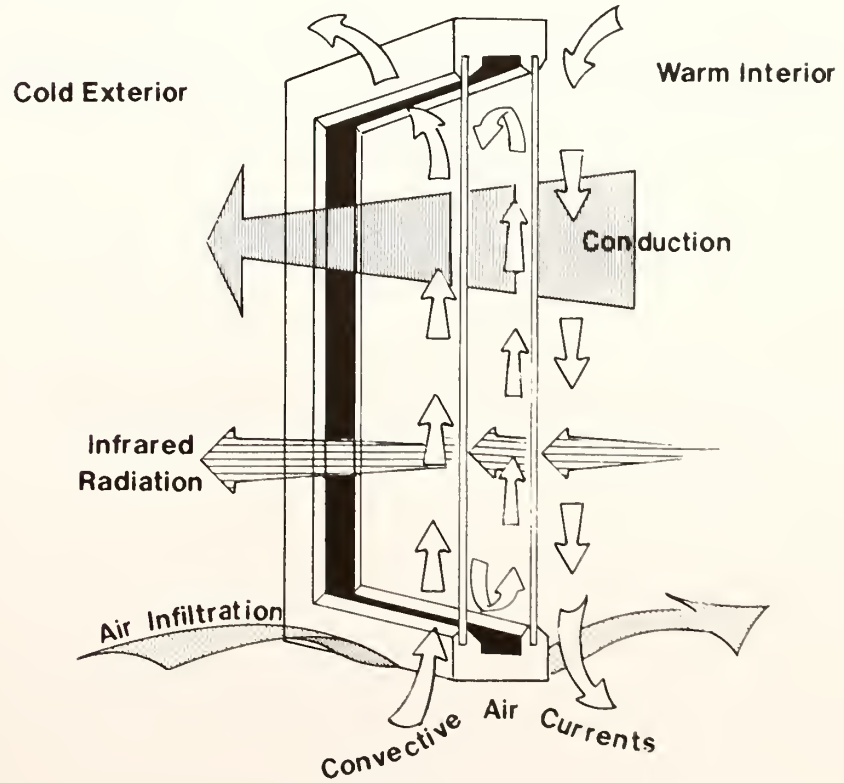
Energy-Efficient Windows and Window Coverings

An information handbook was prepared by Brookhaven National Laboratory after a review and assessment of the vast amount of published literature, available technical research reports, and other material that concern the topic of energy-efficient windows and window coverings. Information was also obtained through communications with representatives of the window industry and window trade associations, whose input and assistance were of great value.

The publication was developed to provide an information base on commercially available energy-efficient windows and window coverings, and is intended for use by Naval housing offices and maintenance personnel who are directly involved with the procurement, installation, and maintenance of windows in residential Naval housing. The purpose of the information is to supply users at the local activity level with the background necessary to make an informed decision on the selection of energy-efficient windows and window coverings for retrofit or for new construction of Navy housing.

A basic implementation process is described in Chapter 1, which outlines the procedure for selecting, procuring, installing, and operating thermally-efficient windows and window coverings. Chapter 2 provides some general information on the types of windows and window coverings considered. Chapter 3 discusses the window and window covering options that are currently available, and their suitability for Navy housing. Chapter 4 provides general guidance on the planning and selection of thermally-efficient windows and window coverings. In this chapter, a Field Survey sheet is also presented, along with Worksheet forms, which are to be used prior to conducting an economic analysis. The survey sheet facilitates the evaluation of the existing window stock in the

WINDOW HEAT LOSS



building. The worksheets serve as a method of calculating the potential savings from a window retrofit option, in comparison to the windows already in place. An example is included in this chapter to illustrate how the sheets are used, and life-cycling costing techniques are also shown. In Chapter 5, a summary of recommendations for the selection of windows and window coverings for Navy housing is given, and suggested inputs to various Navy documents are outlined. Finally, Chapters 6 and 7 discuss general procedural guidelines for the installation, maintenance, and operation of energy-efficient window and window covering options.

The selection of energy-efficient windows and window coverings, supported by a cost/benefit analysis, can effectively reduce the energy consumption for space heating and cooling in residential-type Naval housing. Considering that an estimated 90,000 housing units in the Navy and Marine Corps inventory currently exists today, the potential for cost and energy savings can be significant.

FOR ADDITIONAL INFORMATION: Dr. Suresh C. Garg, Code L73, Naval Civil Engineering Laboratory, Port Hueneme, CA 93043; (805)982-1325.

NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Licensing Opportunity

Copper Chloride Cathode for Liquid-Sodium Cell

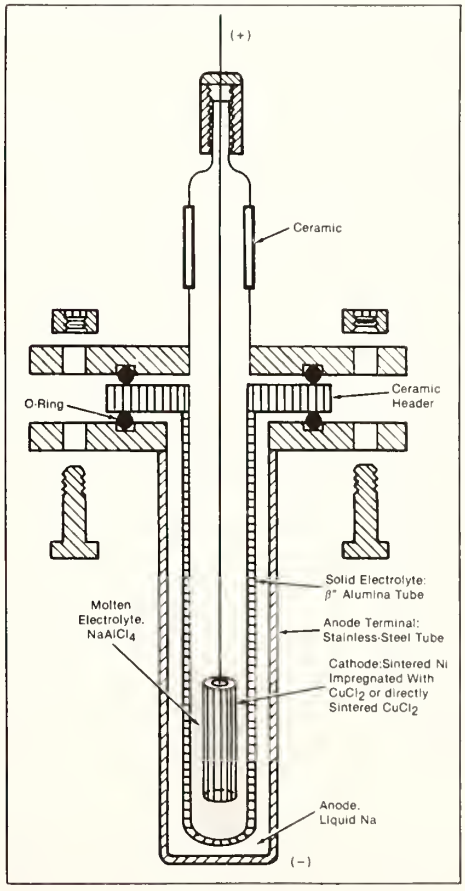
Energy density is higher than that of previous liquid-sodium cells.

A rechargeable liquid-sodium cell with a copper chloride cathode offers a substantial increase in energy density over cells made with other cathode materials. The unit has a theoretical maximum energy density of 1135 W•h/kg, whereas the best previously available cathodes — ferrous chloride and nickel chloride — were limited to energy densities of 1000 to 1070 W•h/kg.

The cell generates electricity by the electrochemical reaction of molten sodium and solid copper chloride immersed in a molten electrolyte, sodium tetrachloroaluminate ($NaAlCl_4$), at a temperature of ≥200 °C. A wall of solid electrolyte, β'' alumina, separates the anode from the cathode (see figure). The cathode consists of porous sintered nickel impregnated with copper chloride, or of a directly sintered copper chloride cathode in the discharged state.

Copper chloride provides a higher energy density by virtue of its large cell potential ~2.85 V; i.e., 0.25 V higher than that of nickel chloride and 0.5 V higher than that of ferrous chloride. Moreover, the conductivity of the copper chloride electrode increases as the discharge proceeds, because metallic copper collects in it. Thus, the battery can be discharged at higher power densities.

The **Wall of the Alumina Tube** separates the molten electrolyte from the molten sodium anode. The copper chloride cathode is embedded in the pores of a sintered nickel cylinder or directly sintered.



This work was done by Ratnakumar V. Bugga, Salvador DiStefano, Ganesan Nagasubramanian and Clyde P. Bankston of Caltech for **NASA's Jet Propulsion Laboratory.**

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA's Resident Office-JPL. Refer to NPO-17640/TN.

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Department of Energy

Technology Application

Solar Energy Research Institute

FLAP Structural Dynamics Code

SERI engineers have developed a highly accurate, computerized design tool that can help improve wind turbine reliability. Available in FORTRAN 77 for use on a personal computer, the Force and Loads Analysis Program (FLAP) predicts the loads on a wind turbine blade as it rotates.

FLAP is a well-documented, easy-to-use tool requiring minimal input. Engineers will find FLAP useful in predicting blade loads for preliminary wind turbine design. It can also be used to study the effects of fluctuating wind components on blade loads.

FLAP was originally developed at Oregon State University to analyze the structural behavior of wind turbines with rigid hubs. SERI researchers refined the program to analyze teetered rotors as well. The new version also accounts for the important effects of wind speed, wind shear, and tower shadow. Rotors that are tilted or yawed relative to the mean wind direction can be accommodated easily.

FLAP can be obtained on floppy disk, along with a report documenting its use, from SERI's Wind Research Branch. Limited technical support for program installation is also available.

For Additional Information:

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Solar Energy Research Institute
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Golden, CO 80401-3393
(303) 231-7303

Refer to Volume XII, Number 3/TN

Engineering

0039 Adapter for 700 Series Flo-Lok Coupling for Single-Point Attachment Operation (Licensing Opportunity)
0040 Catalysts Improve Industrial Processes (Licensing Opportunity)
0041 Method of Recovering Adsorbed Liquid Compounds From Molecular Sieve Columns (Licensing Opportunity)
0042 Microbubble Flotation Development Unit
0043 Remote Sample Bottle Opener (Licensing Opportunity)
0044 Analysis of Stepped Labyrinth Seals—Rotodynamic coefficients are derived for compressible flow.
0045 Estimability and Regulability of Linear Systems—These properties provide criteria for reductions of errors and cost functions in control systems.
0046 Flow-Control Unit for Nitrogen and Hydrogen Gases—a replaceable unit connects to a single manifold plate for ease of service. (Licensing Opportunity)
0047 Piezoelectric Pushers Suppress Vibrations—Actuators are small, lightweight, and rugged.
0048 Helmet-Mounted Visual Display for Flight Simulation—Optical fibers transmit wide-angle images in response to motions of the head. (Licensing Opportunity)
0049 Reducing Aerodynamic Drag of Bluff Bodies—The simple addition of two panels eliminates as much as 80 percent of drag. (Licensing Opportunity)

Testing & Instrumentation

0050 Solid/Liquid Flow Measurement Using Refractive Index Matching
0051 Measuring Flow in the Space Shuttle
0052 Pressure-Measuring Diaphragm Transmits Optical Signals—A sapphire diaphragm would reduce the required number of instrumentation ports. (Licensing Opportunity)
0053 Shaft-Rotation Detector—Rotation is deduced from a subtle component of vibration. (Licensing Opportunity)
0054 Ultrasonic Monitor to Determine Crack-Opening Load—Harmonics of acoustical signals are generated by cracks.
0055 Vacuum-Guage Connection for Shipping Container—An external connector enables measurement of the vacuum in a stored part.

Other Items of Interest

0033 Advanced Combustion System for Industrial Boilers
0036 Energy-Efficient Windows and Window Coverings
0083 Holographic Reticle—This device could be used for noncontacting, nondestructive inspection of surfaces.
0105 Measurement of Water Sprays Generated by Airplane Tires—Water sprays produced by tires on wet runways are simulated and analyzed.
0106 Predicting Unsteady Aeroelastic Behavior—The equations for the motion of the wing and the flow field are solved iteratively and simultaneously.

Department of Energy

Technology Application

Idaho National Engineering Laboratory

Adapter for 700 Series Flo-Lok Coupling for Single-Point Attachment Operation

A housing was designed to provide a single-point attachment location for a 700 Series Flo-Lok coupling. It was intended for the housing to simplify the connecting and disconnecting of the coupling while remote handling equipment was in use. A single-point is generally the easiest type of connector to operate remotely. This is because the connector is gripped and moved in the direction of making up or breaking the connection. The Flo-Lok quick disconnect fluid couplings are particularly easy to operate, as well as light and inexpensive. The design doesn't require welding parts to the connector, which avoids potential material damage. The housing uses a female guide around the female connector, a male housing around the male connector, and two rings for engaging and disengaging the Flo-Lok coupling remotely.

The adapter is for use in any hot-cell operation where remote procedures are needed for operation of maintenance. Potential application at DOE facilities for nuclear fuel and radioactive waste processing is high.

Laboratory Name: Idaho National Engineering Laboratory.

Reference No.: DOE-INEL-054

Patent Status: Patent pending. Available for licensing.

FOR ADDITIONAL INFORMATION: Campbell, R.R., Executive Vice President, Westinghouse Idaho Nuclear Co., Inc., P.O. Box 4000, Idaho Falls, ID 83403; Telephone: FTS: 583-0997; Commercial: (208)526-0997.

Department of Energy

Technology Application

Ames Laboratory

Catalysts Improve Industrial Processes

Hydrodesulfurization, the catalytic process that removes organically bound sulfur from crude oil, is one of the largest volume industrial processes in the United States. Conventional hydrodesulfurization catalysts consist primarily of molybdenum disulfide. However, these catalysts have relatively high oxidation states that may not be optical for hydrodesulfurization. Further, because of the complex and amorphous nature of these catalysts, they are difficult to characterize and scientists have not been able to identify the active sites or phases. Ames Laboratory scientists have developed new hydrodesulfurization catalysts using Chevrel phases that show superior activity and seleetivity, thus conserving large volumes of hydrogen required for conventional catalysts. The amount of hydrogen that can be saved using these catalysts translates into hundreds of millions of dollars annually. One of the most important characteristics of these Chevrel compounds is that their oxidation state is between +2 2/3, rather than +4. This low oxidation state is believed to be responsible for the superior eatalytie properties of Chevrel phases. Other advantages derive from the structure, which is very different from conventional catalysts. Distorted molybdenum octahedra have apexes which lie slightly outside the face centers of a distorted eube of sulfur atoms. This structure makes it possible to insert small, medium, or large metal cations into the position where they will promote the hydrodesulfurization process. Over 40 metals may be incorporated into the Chevrel phase structure, which makes it possible to design a wide range of promotional activity into the catalyst.

Chevrel phases have application in hydrodesulfurization and hydrodenitrogenation of petroleum distillates, coal-derived liquids, and residual oils. Flue gas desulfurization is another potential application.

Literature: M.E. Ekman, J.W. Anderegg, and G.L. Schrader, "Reduced Molybdenum Formal Oxidation States in Hydrodesulfurization Catalysis by Chevrel Phases," *Journal of Catalysis*, Vol. 117, pp. 246-247, 1989.

Laboratory Name: Ames Laboratory.

Reference No.: AL-89-02.

Patent Status: U.S. Patent No. 4,560,470.

FOR ADDITIONAL INFORMATION: Williams, D.E., Office of Research and Technology Applications, Ames Laboratory, 119 Offiee and Laboratory, lowa State University, Ames, lowa 50011; Telephone: Commereial: (515)294-2635.

Department of Energy

Technology Application

Ames Laboratory

Method of Recovering Adsorbed Liquid Compounds From Molecular Sieve Columns

Ethanol is the only synthetic fuel produced in significant quantities in the United States. It can be concentrated from aqueous solutions such as fermentation beer and then be used as a motor fuel or mixed with gasoline to produce gasohol. However, traditional distillation methods for separating ethanol from aqueous solutions require large amounts of heat energy. Ames Laboratory chemists have developed a method for separating ethanol. In this method, ethanol is adsorbed onto a silicalite molecular sieve. This unusual adsorbent is hydrophobic and has an affinity for small organic molecules. In carrying out the process, the feed stock liquid is passed through a column filled with silicalite. By this method, ethanol with a purity of 98 percent is retained within the pores of silicalite. Adsorption is rapid, selective, and efficient over a wide range of alcoholic solution. Ethanol is then recovered from the sieve by heating it at a moderate temperature, applying a vacuum, or stripping it with a gas such as carbon dioxide.

The project applies to the recovery of residual alcohol from fermentation liquids.

Literature: C.D. Chriswell and R. Markuszewski, "Use of a Hydrophobic Molecular Sieve for the Separation of Alcohol from Dilute Aqueous Solutions," *Interfacial Phenomena in Biotechnology and Materials Processing*, edited by Y.A. Attia, B.M. Moudgil and S. Chandler, Elsevier Science Publishers, Amsterdam, 1988.

Laboratory Name: Ames Laboratory.

Reference No.: AL-89-04.

Patent Status: U.S. Patent No. 4,277,635.

FOR ADDITIONAL INFORMATION: Williams, D.E., Office of Research and Technology Application, Ames Laboratory, 119 Office and Laboratory, Iowa State University, Ames, Iowa 50011; Telephone: Commercial: (515)294-2635.

Pittsburgh Energy Technology Center

Microbubble Flotation Development Unit

Froth flotation is generally recognized as the best available technique for cleaning fine coal. However, the efficiency of this process decreases rapidly as the particles get smaller. Extensive fundamental studies carried out since 1980 at Virginia Polytechnical Institute, in conjunction with Pittsburgh Energy Technology Center, have suggested that many of the problems encountered in separating fine particles can be alleviated by using significantly smaller air bubbles than those used in conventional flotation processes. Virginia Polytechnical Institute has developed a froth flotation unit that uses microbubbles and a unique column. The column contains an in-line bubble generator that allows the recirculation of the waste stream to help generate microbubbles, thereby minimizing water consumption and increasing the residence time of coal particles in the column. The microbubble flotation process gives improved recovery of clean coal with improved rejection of ash as compared to the conventional process that uses larger bubbles. The microbubbles can be as small as 20 microns, but their mean diameter is about 50 to 100 microns. Smaller bubbles produce an increased recovery rate, attributable to an improved bubble/particle collision efficiency. Their size may also improve process selectivity (separation of coal and minerals), possibly because microbubbles provide calm flow conditions. Selectivity is further improved because a stream of water (wash water) is passed through the column, carrying entrained mineral matter out between the bubbles and minimizing the transport of such matter into the clean froth product. The design of this unit has many advantages over conventional froth flotation. It can generate bubbles by recirculating the pulp. There is no need to add external water for bubble generation. It is durable and has a modular construction for easy repairs. Because it has few moving parts, replacement and repair are kept to a minimum.

Literature: Yianatos, J.G. et al., "Effect of Column Height on Flotation Column Performance," SMA Annual Meeting, Denver, CO, Preprint No. 87-24, February 24-27, 1987. Yoon, R.H., G.T. Adel, and G.H. Luttrell, 1987. "Development of the Microbubble Column Flotation Process," Proceedings, Second International Conference of Processing and Utilization of High Sulfur Coals, Carbondale, Illinois, September 27-October 1, 1987.

Laboratory Name: Pittsburgh Energy Technology Center.

Reference No.: DOE/PETC-3

Patent Status: Not patented.

FOR ADDITIONAL INFORMATION: Downey, K., Pittsburgh Energy Technology Center, Box 10940, Pittsburgh, PA 15236; Telephone: FTS: 723-6029; Commercial: (412)892-6029.

Department of Energy

Technology Application

Idaho National Engineering Laboratory

Remote Sample Bottle Opener

The remote sample bottle opener uses two small air-powered cylinders to open bottles of radioactive samples. One cylinder clamps an arm and a bearing against the lid of the bottle, forcing the lid against a stationary mounted bearing and a rotary reduction rubber drive air motor. When air is supplied to the air motor, the rubber mounted wheel turns, removing the sample bottle lid. The device can also be used to screw on lids. It adjusts to a wide range of cap sizes. The open bottle is removed by a manipulator hand and the contaminated cap falls into a disposal container below when the air pressure is relieved.

The technology could be used in laboratories and hot cells where remote operations are necessary to take off or put on sample bottle lids.

Laboratory Name: Idaho National Engineering Laboratory.

Reference No.: DOE-INEL-056.

Patent Status: Not patented. Available for licensing.

FOR ADDITIONAL INFORMATION: Campbell, R.R., Executive Vice President, Westinghouse Idaho Nuclear Co., Inc., P.O. Box 4000, Idaho Falls, ID 83403; Telephone: FTS: 583-0997; Commercial: (208)526-0997.

NASA Tech Brief
National Aeronautics and
Space Administration

Analysis of Stepped Labyrinth Seals

Rotordynamic coefficients are derived for compressible flow.

A report presents an analysis of compressible flow in a stepped labyrinth gas seal in a turbomachine. This analysis is part of a continuing effort to understand and suppress self-excited vibrations caused by stepped labyrinth seals. It is derived from a previous analysis of straight-through labyrinth seals.

The analysis is based on the following assumptions:

1. The fluid is an ideal gas.
2. Variations in pressure within a cavity of the seal are small compared with the differences in pressure across a seal strip.
3. The lowest frequency of acoustic resonance in the cavity is much higher than the speed of the rotor.
4. The eccentricity of the rotor is small compared to the radial seal clearance.
5. Although the shear stress is significant in the determination of the flow parameters (velocity, etc.), the shear-stress forces on the rotor are small when compared to the pressure forces.
6. The flow in the cavity is turbulent and isothermal.
7. Added mass terms are neglected.
8. The seal strips are midway between steps.

The equations of continuity and conservation of momentum are presented for a single-cavity control-volume model of each step of the seal. Axial leakage between steps is represented by a choked-flow model. The resulting governing equations are linearized by a perturbation treatment for small motion about a central position, taking zeroth- and first-order terms in an expansion in the eccentricity ratio.

The zeroth-order leakage equation is solved iteratively to obtain zeroth-order pressures in the cavities. The zeroth-order circumferential momentum equation is solved by a Newton root-finding technique to obtain zeroth-order circumferential components of velocities in the cavities. Under the assumption of an elliptical orbit for the shaft and a corresponding harmonic response in the distributions of velocity and pressure, the first-order equations of continuity and conservation of momentum are reduced to linearly-independent, algebraic equations in a separation-of-variables approach. The resulting first-order distribution of pressure is integrated along and around the shaft to obtain the reaction force developed by flow through the seal and the corresponding rotordynamic coefficients.

The results of these calculations are presented in the form of a parametric study because there are no known experimental data for the rotordynamic coefficients of stepped labyrinth gas seals. The parametric study investigates the relative rotordynamic stabilities of convergent, straight, and divergent stepped labyrinth gas seals. The results show that, generally, divergent seals are more stable, rotordynamically, than are straight or convergent seals. The results also show that, contrary to the conclusion drawn from a previous experiment on a 15-tooth seal, the teeth-on-stator seals are not always more-stable rotordynamically than are the teeth-on-rotor seals.

This work was done by Joseph K. Scharrer of Rockwell International Corp. for **Marshall Space Flight Center.** *"Stepped Labyrinth Gas Seal Program." MFS-29585/TN*

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration

Estimability and Regulability of Linear Systems

These properties provide criteria for reductions of errors and cost functions in control systems.

A report presents two new properties of systems characterized by linear state space models (e.g., dynamical systems and associated control systems): estimability and regulability. These properties are useful in the design of optimal controllers and estimators.

The benefit of using observation or feedback signals in estimating the states or the regulation of dynamical systems is normally manifested by the reduction of certain cost functions with respect to the values taken by those functions when no such signals are used. The new properties yield reductions in the mean-square errors in the estimates of the states and in the quadratic cost functions in state-feedback control. Estimability and regulability are different from observability and controllability, which were introduced by Kalman and are widely recognized as key structural properties in linear estimation and control.

A stochastic linear system is said to be estimable if, in estimating its state from its output, the posterior error covariance matrix is strictly smaller than the prior state covariance matrix. This condition is equivalent to the condition that no direction in the state space at any time is orthogonal to all the past observations. It is also shown to be equivalent to the reachability of a certain pair of matrices, related to the covariance function of the observations process. The notion of estimability is independent of that of observability in the sense that one does not imply the other.

When a system is not estimable, the corresponding Kalman filter can be reduced to a lower-order estimator of the state process. A linear-state-space system driven by white noise is shown to be a minimal-order realization of its output process if and only if it is observable and estimable. These results apply to time-variant and time-invariant linear systems in discrete and continuous time. In the stationary case, the estimability condition leads directly to conditions for minimality of the Kalman filter.

A linear system is said to be regulable if, for any nonzero initial condition, the quadratic cost in applying optimal control is strictly smaller than the cost when no control is applied. This means that when a system is not regulable, the feedback signal may be eliminated for some nonzero initial condition without increasing the cost. Necessary and sufficient conditions for regulability are obtained for time-variant and time-invariant systems. The regulability condition is the same as the condition for the complete dependence of the regulation problem, which in turn has been shown previously to be equivalent to the irreducibility of the optimal linear quadratic regulator.

It is shown that the estimability condition and the regulability condition, which involve the Lyapunov equation and the time-reversed Lyapunov equation, respectively, are similar, modulo time reversal. Such similarity, which has also been shown to exist between the Riccati equations associated with the estimation and the regulation problems, has been termed "duality" in the literature. The duality between the estimability and the regulability properties is then shown to be consistent with the one between the Lyapunov and the Riccati equations corresponding to the estimation and the regulation problems. Next, by use of this duality, the regulability condition is obtained from the estimability condition.

This work was done by Yoram Baram of **Ames Research Center** *and Thomas Kailath of Stanford University. "Estimability and Regulability of Linear Systems."*
ARC-12173/TN

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
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NASA Tech Brief
National Aeronautics and Space Administration
Ames Research Center, Moffett Field, California

Licensing Opportunity

Flow-Control Unit for Nitrogen and Hydrogen Gases

A replaceable unit connects to a single manifold plate for ease of service.

A gas-flow-control unit (see figure) that can be installed and removed as one piece replaces a system that included nine separately serviced components. The unit controls and monitors the flows of nitrogen and hydrogen gases. The unit is designed for connection via a fluid-interface manifold plate, reducing the number of mechanical fluid-interface connections from 18 to 1, and reducing the time required for maintenance.

Compared to the original system, the unit provides the following:

- A reduction in mass of 78 percent, from 29.8 to 6.5 lb (13.5 to 2.9 kg);
- A reduction in volume of 77 percent, from 440 to 100 in.^{3} (7,210 to 1,640 cm^3); and
- A reduction in power consumption of 91 percent, from 21 to 2 W.

This redesign is an engineering case study in techniques for increasing reliability, safety, and ease of maintenance, and for reducing weight, volume, and power consumption.

The unit performs valving, restriction of flow, and sensing of pressure during steady-state operation and intermode transitions. It controls reference and purge flows of nitrogen, production flow of nitrogen, vacuum, and vent flows. Operating gas pressures range up to 300 psia (2 MPa); the proof pressure is 750 psia (5 MPa).

The unit includes six two-state (open or closed) valves. Two motor-driven rotary camshafts operate the valves and provide the 14 desired combinations of valve states (out of the 64 possible combinations). Valve transitions take approximately 2 s. Positive-action valve lifters are used instead of return springs. Both visual and electronic valve-position indicators are provided. The valve-position indicator potentiometers are driven by gears to eliminate exposed electrical contacts.

A computerized process controller controls all functions. A manual override and a redundant battery power supply enable actuation of the valves when primary power is lost.

In 30 days of cyclic testing, which included 2,244 operating cycles and tank-filling sequences, the unit demonstrated consistent and accurate valve positioning, exhibited no forward valve leakage at operating pressures, and demonstrated the sensitivity, accuracy, and reliability of sensors of pressure and flow.

This work was done by B.J. Chang and D.W. Novak of Life Systems, Inc., for **Ames Research Center**.

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Ames Research Center. Refer to ARC-11772/TN.

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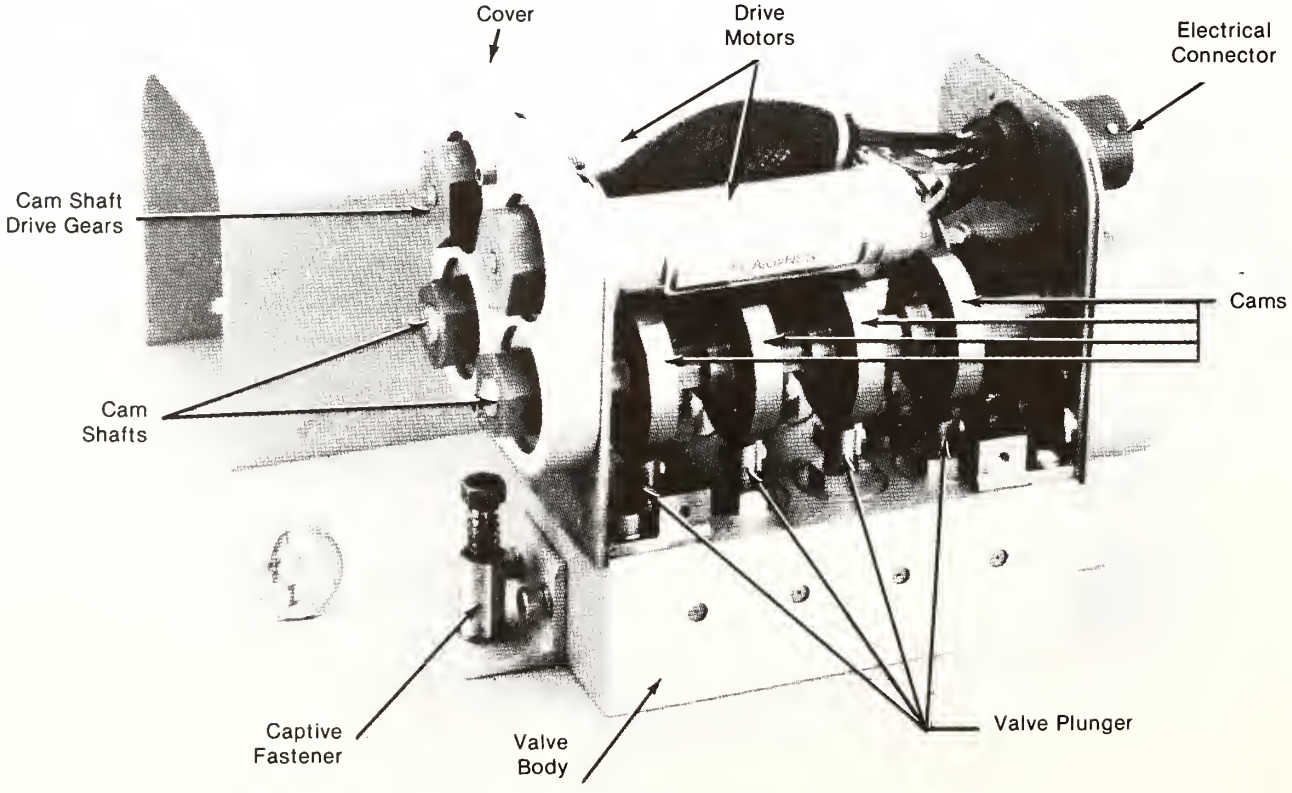

A **Gas-Flow-Control Unit** replaces a system that had nine separately serviced components.

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*

REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and
Space Administration
Lewis Research Center, Cleveland, Ohio

Piezoelectric Pushers Suppress Vibrations

Actuators are small, lightweight, and rugged.

Vibration-suppressing control systems that include piezoelectric actuators are undergoing development. These systems are intended primarily to enhance safety and prevent damage in rotating machinery by sensing and counteracting vibrations. The new systems should be particularly useful in suppressing unpredictable vibrations caused by changes in loads, losses of rotating components (e.g., turbine blades) and the consequent imbalances in rotors, and the ingestion of foreign objects into turbines.

The new systems offer several advantages over other active and passive vibration-suppressing systems. The piezoelectric actuators are compact, light in weight, and capable of operation at temperatures from cryogenic to above ambient. Unlike squeeze-film dampers, they do not require heavy, bulky lubrication systems. In contrast with active magnetic suspension systems, the piezoelectric systems require much simpler electronic control subsystems and do not require large electromagnet coils. Also unlike magnetic systems, piezoelectric systems continue to provide support and some passive damping even when electronic control subsystems or power supplies fail.

In a representative system (see Figure 1), the housing of a ball bearing that supports one end of a rotor shaft is supported by horizontal and vertical piezoelectric actuators. Eddy-current probes, which operate even when submerged in oil or cryogenic liquids, are used to sense the horizontal and vertical vibrations of the bearing and shaft. The outputs of the probes are sent to a relatively simple electronic control subsystem that includes only differentiators, filters, and amplifiers. The output of the control subsystem is fed to amplifiers that drive the piezoelectric actuators. If the control subsystem is designed properly with respect to electronic and mechanical stability and the vibrational modes and damping of the rotor, actuators, and supports, then the amplitudes and phases of the signals applied to the actuators should be such as to oppose the vibrations.

Figure 2 shows the results of an experiment in which one end of a rotor was suspended by a system like that of Figure 1. The rotor was deliberately unbalanced and operated at various speeds, including the critical speeds for the onset of instability caused by resonant coupling between rotations and vibrations. The plots show that with sufficient feedback gain, the ampli-

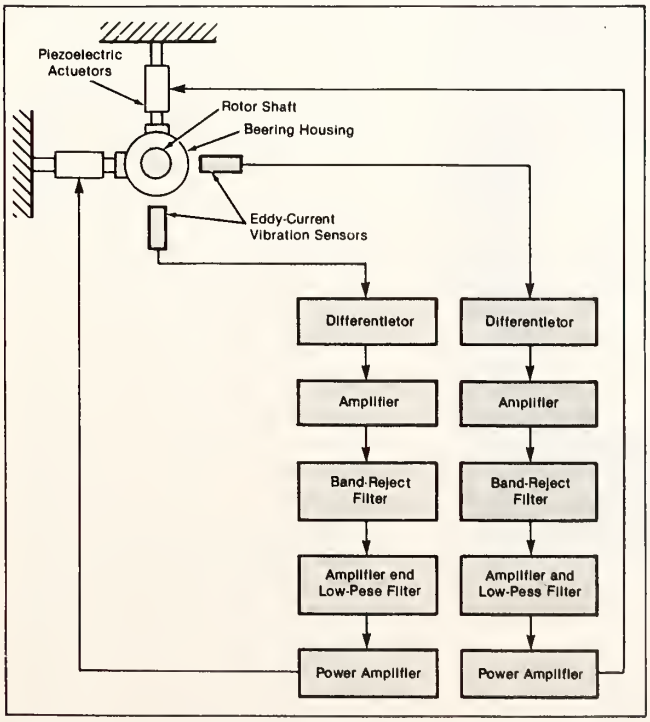

Figure 1 **Piezoelectric Actuators** driven by relatively simple feedback circuits suppress the vibrations of a rotating shaft..

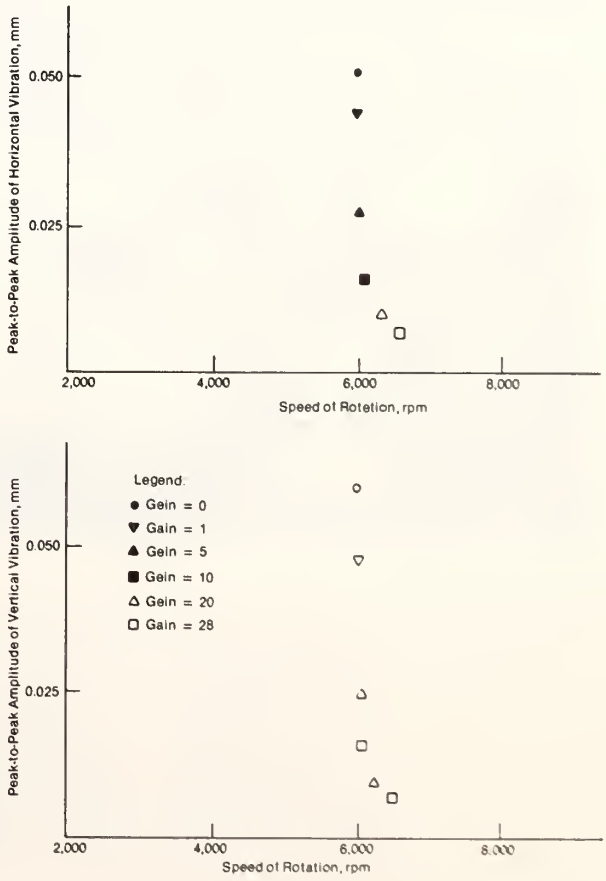

Figure 2. The **Vibrations of a Rotor** suspended as shown schematically in Figure 1 decrease as the feedback gain is increased. The peak near 6,000 rpm is caused by resonant coupling between rotations and vibrations.

tudes of vibrations at the critical frequency are reduced by factors of about 5. The plots also show that the increase in feedback gain increases the critical frequencies for instability. This suggests that one might vary the feedback gain during runup or coastdown to avoid instability as the speed passes through the critical range.

This work was done by Albert F. Kascak of **Lewis Research Center**. *LEW-14927/TN*

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
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NASA Tech Brief
National Aeronautics and Space Administration
Ames Research Center, Moffett Field, California

Licensing Opportunity

Helmet-Mounted Visual Display for Flight Simulation

Optical fibers transmit wide-angle images in response to motions of the head.

A helmet-mounted visual display system (see figure) provides a pilot with a broad range of visual information for flight simulation. Unlike earlier visual systems, the helmet-mounted display offers a nearly unlimited field of regard. No matter how the pilot turns his/her head — sideways, rearward, up, or down — the display shows the image that the pilot would see in a real situation. In this respect, it is superior to cathode-ray-tube "window" displays, and even to dome projection displays. Moreover, the image is bright and undistorted.

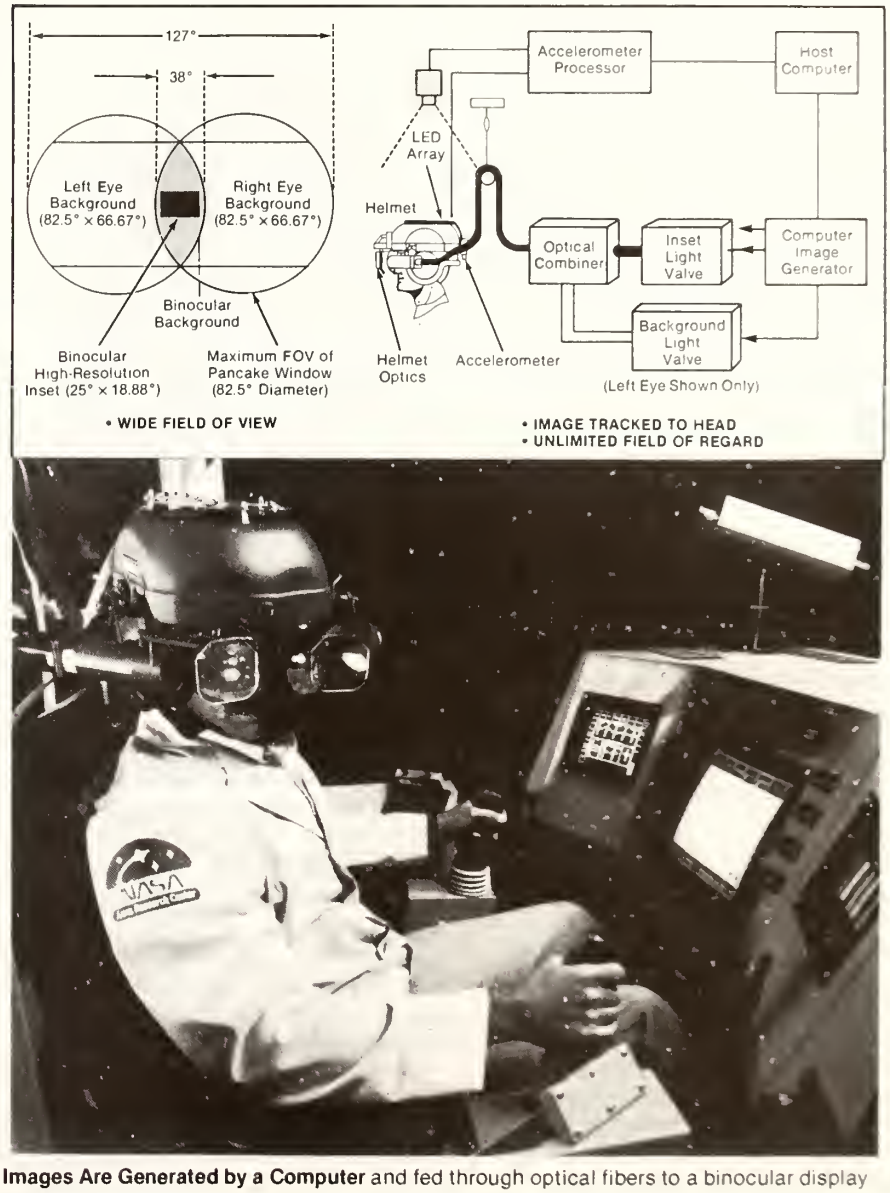
Two "pancake" lenses are mounted on a lightweight helmet. A cable of optical fibers carries images to each lens. "Light-valve" projectors deliver the computer-generated binocular images to the cables.

Four overhead infrared cameras track the motion of the pilot's head by monitoring a ring of light-emitting diodes on the helmet. A sensor on the rear of the helmet measures the rate of acceleration. With the video and rate data, the host computer can calculate and anticipate the position of the head and direct the display computer to generate the appropriate binocular images, in real time.

The pilot sees two overlapping displays — one for each eye — and a high-resolution inset field in the overlap (middle) region for heads-up-display symbology. The pilot can see cockpit displays and controls through the optics. A software model of the aircraft structure in the display computer prevents the pilot from seeing through the simulated aircraft structure.

A helmet is custom-fitted for each pilot so that it rests securely and comfortably on the head, and the optics are aligned. During the fitting of a helmet, precise measurements of the pilot's interpupillary distance, eye relief, and anomalies of the positions of the eye are made. Then, during the assembly of the helmet, the mounting fixtures for optics are set for the pilot. These adjustments ensure that the exit pupils of the optics coincide with the pilot's pupils as soon as the optics are placed on the helmet, so that there is no need for time-consuming adjustments.

Because the optical elements of the display are costly, they are not permanently mounted in a helmet. Instead, the helmets are designed so that the optics can be quickly inserted at the beginning of a simulation session and just as quickly removed for use by another pilot.



Images Are Generated by a Computer and fed through optical fibers to a binocular display mounted on a helmet.

This work was done by Anthony M. Cook of **Ames Research Center.**

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Ames Research Center. Refer to ARC-12160/TN.

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REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration
Langley Research Center, Hampton, Virginia

Licensing Opportunity

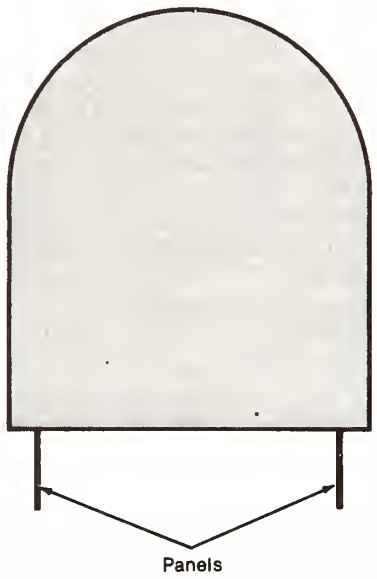
Reducing Aerodynamic Drag of Bluff Bodies

The simple addition of two panels eliminates as much as 80 percent of drag.

A new method has been found to reduce the aerodynamic drag of noncircular bluff bodies like road-transport vehicles. The drag on such bodies consists mainly of pressure drag. The flow fields are usually characterized by large wakes and periodic vortex shedding. Substantial amounts of energy can be required to overcome the high drag forces associated with such flow patterns.

The Reynolds number associated with small- and medium-size road vehicles usually falls in the subcritical (1.0 to 2.0×10^6) range. A popular conventional method of reducing the aerodynamic drag of noncircular bluff bodies at subcritical Reynolds numbers is the rounding of sharp corners, which can reduce drag by as much as about 50 percent. The new method consists of the installation of thin, flat panels on the forward side of the body, facing the airstream (see figure). This concept was developed using two-dimensional wind- and water-tunnel tests on a typical noncircular cylinder.

Panels of various sizes were employed, and their locations on the windward side were varied systematically. Detailed pressure measurements with Reynolds numbers in the subcritical range were performed in a low-speed, open-circuit wind tunnel having a maximum velocity of 115 ft/s (35 m/s). Measured surface pressures were integrated to obtain drag coefficients, and the test results were corrected for blockage effects. Systematic water-tunnel flow-visualization tests (Reynolds number = 6,000) were also carried out. Both the height and the locations of the panels have a strong influence on the drag coefficient. The maximum reduction of drag obtained in this investigation was 81.5 percent.



Thin, Flat Panels on the Front of a bluff body produce a streamlining effect over the body.

The panels produce a streamlining effect over the body. The width of the wake is reduced, and vortex shedding is greatly suppressed, as evidenced by flow-visualization photographs. This effect is caused by the transition in the flow consequent to separation at the panels and subsequent smooth reattachment to the body. The reattached flow continues along the surface but eventually separates. This type of flow pattern is typical of flow around bluff bodies at supercritical Reynolds numbers, and the associated drag coefficient is well below the subcritical value. Thus, the panels have made supercritical flow possible at subcritical Reynolds numbers.

A novel feature of this technique is the generation of significant suction over the windward face. With panels on the windward face, the positive pressures are confined to the region bounded by the panels. Between the panels and the windward corners, high suction is produced by the sharp turning of the flow. These negative pressures contribute significantly to the reduction of drag and are responsible for the drastic fall in the drag coefficient.

The installation of flat panels is quite simple and should not require a major modification of the shape and size of the body to which they are attached. This technique could have significant potential for trucks, buses, automobiles, trains, surface ships, and submarines.

This work was done by Lawrence W. Taylor, Jr., of **Langley Research Center.**

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center. Refer to LAR-13768/TN.

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Pittsburgh Energy Technology Center

Solid/Liquid Flow Measurement Using Refractive Index Matching

Four types of flows occur in a pipeline carrying an unstabilized coal water slurry. First, if the slurry is left immobile for a sufficiently long time, solid particles settle at the bottom. Once the flow is resumed, the fluid at the top begins to carry along a small amount of solid particles that are removed from the top of the sludgelike solid layer. This is called flow with a stationary bed. If the velocity of the liquid is increased, a substantial amount of solid particles begins to be moved by the liquid and rolls over the remaining layer of sludge. This is called saltation flow. With further increase in velocity, all the solid particles begin to move, but they remain concentrated at the bottom of the pipe. This is called heterogeneous flow. Finally, when velocity is again increased, the solid and liquid mix uniformly and flow together. This is called homogeneous flow. A unique refractive index matched test facility has been developed by Case Western Reserve for studying solid/liquid multiphase flow as applied to coal water slurries. The facility was placed on line in 1989 and was funded through the Solids Transport Program of the Pittsburgh Energy Technology Center. Case Western Reserve combined laser doppler velocimetry (LDV) with refractive index matching (RIM) to produce a precise method for studying multiphase flows. In LDV, a beam (usually of the blue wavelength) is split into two equal beams, then refocused at a particular point in the pipeline. The refocused beams interact to form alternate regions of low and high intensity - the fringe pattern. Small particles moving with the fluid scatter light from the high-intensity areas. As the particles move from blue to black, their velocity is determined from the change in frequency (Doppler shift) of the light they emit. From the particle velocity, the fluid velocity can be inferred.

Literature: Kadambi, J.R., A. Dybbs, and S. Bhunia "Laser Anemomentry Measurements of Solid-Liquid Multiphase Flow Using Refractive Index Matched Technique," Third International ASME Symposium on Liquid-Solid Flows, Winter Annual Meeting Chicago, Illinois, December 1988. Kadambi, J.R. et al., "Measurements of Solid Liquid Multiphase Flow Using Refractive Index Matching Techniques," Third International Conference on Laser Anemometry, Advances and Applications, University College of Swansea, Wales, September 1989.

Laboratory Name: Pittsburgh Energy Technology Center.

Reference No.: PETC-2.

Patent Status: Not patented.

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NIST Technology Update

National Institute of Standards & Technology
U.S. Department of Commerce, Gaithersburg, MD 20899

Measuring Flow in the Space Shuttle

NIST scientists are solving one of the world's trickiest measurement problems - gaging the super-fast flow (up to 185 ft/sec) of liquid oxygen in ducts of the space shuttle main engine. Accurate measurement is important to obtain maximum fuel efficiency in the huge engine. The flow velocity is almost 10 times greater than the maximum for which commercial flowmeters are designed. To make matters worse, the ducts are continuously curved, leaving very little space to install the meters. In smaller ducts, the meter has to be inserted through an instrument port less than half an inch in diameter. A NIST researcher has designed vortex shedding flowmeters, which have been tested with both water and liquid nitrogen. Some meters have measured flows up to 180 ft/sec and can fit into the instrument ports. More testing is needed, and more work is required with sensors designed to convert the flow rate into electrical signals for readouts.

FOR ADDITIONAL INFORMATION: Two papers discussing the project are available from Jo Emery, Div. 104, NIST, Boulder, Colo. 80303; 303/497-3237. Ask for no. 31-90.

NASA Tech Brief
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama

Licensing Opportunity

Pressure-Measuring Diaphragm Transmits Optical Signals

A sapphire diaphragm would reduce the required number of instrumentation ports.

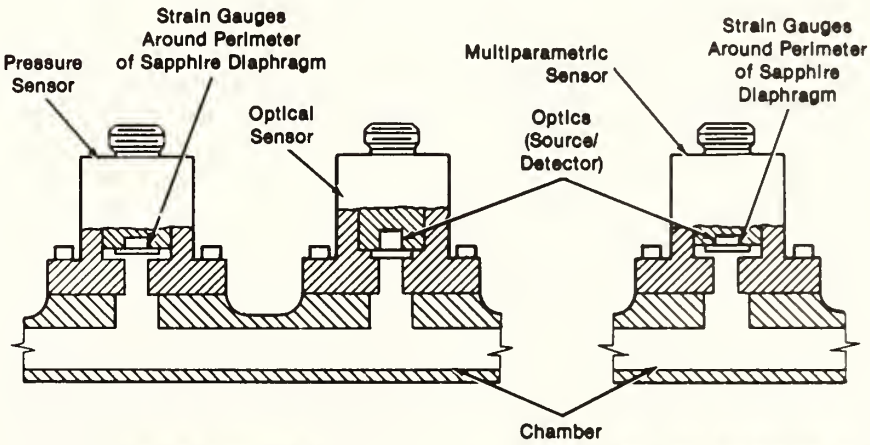
A proposed sapphire diaphragm would perform two functions in an instrumented research engine or pressure vessel. It would serve both as a pressure sensor and as a window for observation, optical probing, or the optical transmission of other measurements.

Strain gauges around the edge of the diaphragm would measure the deflection caused by pressure or vacuum in the vessel. As a window, the transparent diaphragm would transmit light from a source to the interior of the vessel and would carry light from the vessel to a light detector.

Increasingly, single-crystal sapphire is becoming the material of choice, replacing metal in pressure-sensor diaphragms because it offers high stability and a wide range of operating pressures. At the same time, sapphire is being used more and more as a transmission medium for pyrometers, spectrometers, and other instruments used to observe phenomena inside high-pressure (or high-vacuum) vessels. In the proposed application, the combined features of sapphire would be exploited so that only one window would be needed for both optical and pressure measurements (see figure).

This work was done by Arthur J. Hill of Rockwell International Corp. for **Marshall Space Flight Center.** *No further documentation is available.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center. Refer to MFS-29535/TN.



Deflections of the Sapphire Diaphragm would alter the resistances of strain gauges mounted around its periphery. At the same time, the transparent material would enable optical measurements of conditions in the chamber. Thus, additional information could be obtained about conditions in the chamber without the need for additional sensor mounts.

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NASA Tech Brief
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama

Licensing Opportunity

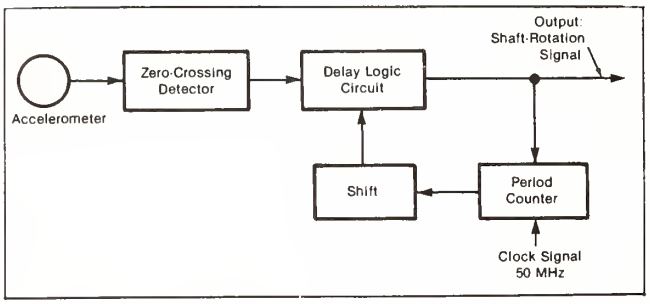
Shaft-Rotation Detector

Rotation is deduced from a subtle component of vibration.

A signal-processing subsystem generates a signal indicative of the rotation of a shaft from the output of an accelerometer mounted on the housing of the bearing that supports the shaft. The output of the subsystem is a binary signal at the frequency of rotation of the shaft. The subsystem is part of an assembly of electronic equipment that measures vibrations in rotating machinery. Some of the other equipment is described in the two preceding articles and the following article. The other equipment uses the binary shaft-speed signal as a phase and frequency reference in the analysis of other vibration signals.

The accelerometer is mounted in such a way as to be sensitive to vibrations of the shaft perpendicular to its axis. The output of the accelerometer includes noise and components of vibration at frequencies higher than the rotational frequency of the shaft. The shaft-rotation-detector subsystem extracts the fundamental-frequency component of the vibration of the shaft (which is presumed to be synchronized with the rotation of the shaft) by acting as a tracking low-pass filter, the cutoff frequency of which is determined iteratively by the measurement itself.

As shown in the figure, the output of the accelerometer is processed through a zero-crossing detector into a delay logic circuit, which recognizes a zero crossing only when it appears to be stable for the equivalent of 1/16 of the current measured period. For this purpose, the period is the period of the binary output of the delay logic circuit, as measured by a counter. The measured period, divided by 16, is loaded into a preset counter to generate the required delay. The binary output of the delay logic circuit is taken to be the shaft-rotation reference signal.



The **Shaft-Rotation Detector** finds a fundamental-frequency component of lateral vibration of a rotating shaft in the output of an accelerometer mounted on the housing of a bearing that supports the shaft. It measures the period of this component, which is assumed to be synchronized with the rotation.

The basic measurement performed by the subsystem — the period corresponding to the rotation of the shaft — is made with a precision of 28 bits. To suppress random errors yet still be able to track changes in speed, the measurements of the 16 most recent periods are averaged exponentially.

The shaft-rotation-detector subsystem detects the shaft-rotation component of the noisy accelerometer signal over the range of frequencies from 0.3 to 500 Hz (18 to 30,000 rpm). The dynamic range of the subsystem greatly exceeds those of analog and phase-locked-loop filter circuits. Its precision, response time, frequency range, and resolution can all be extended, inasmuch as they are all determined by parameters of the digital circuits within it.

This work was done by Richard L. Randall of Rockwell International Corp. for **Marshall Space Flight Center.**

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center. Refer to MFS-29540/TN.

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NASA Tech Brief
National Aeronautics and Space Administration
Langley Research Center, Hampton, Virginia

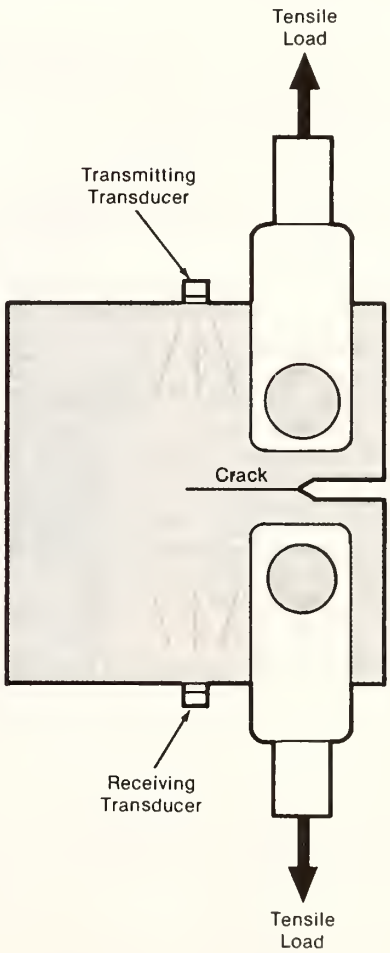
Licensing Opportunity

Ultrasonic Monitor To Determine Crack-Opening Load

Harmonics of acoustical signals are generated by cracks.

A new ultrasonic monitor to determine the crack-opening load in a compact tension specimen uses transducers to pass an acoustic wave across the crack region. Previous methods to determine the condition of full crack opening when the specimen is placed under load suffer from limitations imposed by the equipment used. For example, in the commonly used load-reduced-displacement and load-slope-change methods, an extensiometer is placed at a notch in a compact tension specimen. The extensiometer measures the opening of the notch and, hence, of the crack. By plotting the load against the reduced displacement or against the increase in slope, the load at which the crack is really open can be determined. One of the main disadvantages of these methods is that the signals from strain sensors, such as extensiometers, are noisy. Because of this, there is uncertainty in the determination of the crack-opening load.

The figure shows a compact tension specimen with a transmitting and a receiving transducer mounted so that the acoustic signal passes thrcugh the cracked region. A signal generator sends out a burst of a specific frequency. This signal is amplified and sent to the transmitting transducer, where it excites acoustic waves in the specimen. These waves propagate toward the cracked region. When the crack is closed, the acoustic signal is transmitted across the cracked region by the portions of the two surfaces that are in intimate contact. As the surfaces of the crack begin to separate, the signal propagates only during a portion of the cycle, giving rise to a mechanical "rectification" of the acoustic signal. The action of a barely opened crack is to enrich the relative proportion of the second harmonic of the signal.



An **Acoustic Signal** is transmitted across the crack and partially mechanically "rectified" as the crack opens.

The acoustic signal, as altered by the crack, travels to the receiving transducer, the output of which is processed by a receiver. The frequency is selected by tuning the receiver. The output of the receiver is monitored by an oscilloscope. The process is repeated at different loads while holding the received fundamental-frequency output fixed. The harmonic output is measured and plotted as a function of load.

One advantage of this technique is a definite improvement in signal-to-noise ratio. The process also possesses substantial immunity from the noise that is caused by the operation of the load frame and its associated parts. In addition to applications for the aerospace community, this monitor and concept clearly have general utility in the testing of materials and potentially in nondestructive evaluation of solid parts.

This work was done by William T. Yost of **Langley Research Center.**

This invention has been patented by NASA (U.S. Patent No. 4,823,609). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center. Refer to LAR-13889/TN

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NASA Tech Brief
National Aeronautics and Space Administration
Lyndon B. Johnson Space Center, Houston, Texas

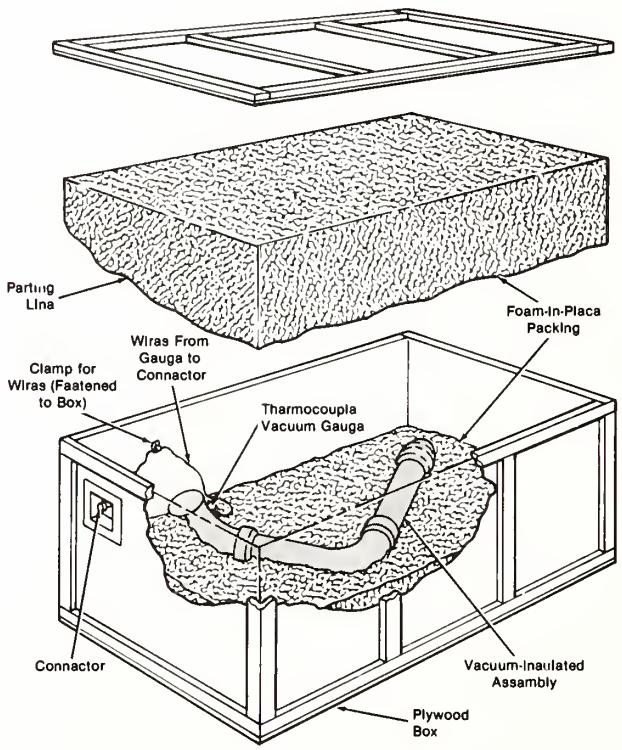
Vacuum-Gauge Connection for Shipping Container

An external connector enables measurement of the vacuum in a stored part.

The vacuums in stored vacuum-insulated parts like cryogenic feedlines must be monitored from time to time to ensure that the vacuums have not deteriorated during storage, because of leakage through defective welds or the like. While such parts often include thermocouple vacuum (that is, low-pressure-measuring) gauges for this purpose, the containers must be opened to gain access to the gauges. This nuisance can be eliminated by mounting a suitable electrical connector in the wall of each container and connecting the gauge to the connector before sealing the container (see figure). The readout meter can then be connected to the gauge without removing the container from storage and opening it. A part that has failed can be returned for repair with its original packing still intact.

The saving in time and money and reduced risk of handling can be considerable for a large part. This technique was used with 17-in. (0.43-m) diameter cryogenic lines that weigh 340 lb (154 kg) apiece. Previously, an overhead crane and special tools had been required to unpack the lines for vacuum checks.

This work was done by Robert H. Henry of Rockwell International Corp. for **Johnson Space Center**. *No further documentation is available. MSC-21523/TN*



A **Remote-Readout Connector** is added to a shipping container and connected to a thermo-couple vacuum gauge in a vacuum-insulated cryogenic line packed in the container. This simple provision enables the monitoring of the condition of the vacuum without opening the container.

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Environmental Science & Technology

0056 Available Models for Estimating Emissions Resulting from Bioremediation: A Review

Testing & Instrumentation

0057 Evaluation of an Anion Exchange Resin for Sampling Ambient Level Phenolic Compounds

0058 Laboratory Method to Estimate Hydrogen Chloride Emission Potential Before Incineration of a Waste

0059 Materials Can Help Evaluate Industrial Atmosphere

Other Items of Interest

0060 Bellows-Sealed 1/4-Turn Ball Valves (Licensing Opportunity)

0066 Damping Seals and Bearings for a Turbomachine—Bearing loads are reduced to prolong service lives. (Licensing Opportunity)

0073 Polyphosphazene Semipermeable Membranes (Licensing Opportunity)

0095 Method for the Recovery of Silver from Silver Zeolite (Licensing Opportunity)

0098 Analyzing Environmental Pollutants (Licensing Opportunity)

0100 High-Temperature Quantitative Dilution Device for Oxides of Nitrogen Measurements via Chemiluminescent Monitors (Licensing Opportunity)

United States
Environmental Protection
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Research and Development

EPA 600 /S3-90/031

EPA

Project Summary

Available Models for Estimating Emissions Resulting from Bioremediation: A Review

Introduction

Biological treatment of organic pollutants offers the advantage of contaminant destruction rather than transfer to other media. Thus, biotreatment systems may provide the potential to reduce or eliminate the human health risks associated with the treatment and/or disposal of hazardous wastes. However, concern has grown in recent years that many volatile organic pollutants are emitted to the atmosphere from biotreatment facilities before they can be degraded. In response to the increased attention, a number of models have been developed that predict the fate of organic pollutants during specific bioremediation processes.

The full report focuses on the potential for bioremediation processes to transfer contaminants between the soil or water and the air. The intent is to identify, describe, and evaluate available methods and models for estimating atmospheric emissions from bioremediation processes used to treat hazardous waste. Models that consider only volatilization will tend to overpredict the magnitude of air emissions from bioremediation processes. Therefore, this report concentrates on models that incorporate the competing effects of biological activity, volatilization, and possibly other mechanisms, such as adsorption and transport, on the fate of organic pollutants. Models of some non-biological components of the treatment processes also are included. Bioremediation processes that are currently in use or in advanced stages of research are listed in the final report, where each process is briefly described in terms of its operation and component parts, the types of contaminants treated, advantages and disadvantages associated with its use, and the likelihood of air emissions.

An extensive literature search was conducted to locate models that simulate the fate of organic pollutants for each biotreatment process. Summaries of the models located during that search make up the bulk of this report. Models are summarized in terms of their theoretical basis, assumptions, and the mechanisms of transport and fate that are considered. Input requirements, output, previous model applications, resource requirements, ease of use, and model availability also are discussed briefly. Air emissions from some biotreatment processes have not been modeled. For those processes, the current status of research is discussed. In addition, the status of modeling two physical remedial processes (i.e., soil washing and soil venting) often used in conjunction with bioremediation efforts is briefly addressed.

A chapter in the full report describes the important pathways by which pollutants are transferred from a waste treatment site. Generally accepted theories associated with each pathway are briefly summarized. In addition, when possible, methods of estimating equilibrium and rate constants are presented.

Current efforts to model the fate of hazardous compounds at biological treatment facilities suffer from a number of limitations that should be understood by users of the models described in the full report. These limitations and the related need for further research are discussed in the final section of the full report.

Conclusions and Research Needs

In order to estimate the magnitude of emissions from biological treatment facilities, overall fate models that incorporate the effects of several competing removal mechanisms are needed. Although such models have been developed for some bioremedial processes, no models exist for other processes. The models that are available are of limited utility both because of limited laboratory and field data and because of the assumptions made in developing the models.

Conclusions drawn from this report are:

1) Models of bioremediation processes are empirical. Data are unknown or incomplete and the interrelationships of components and pathways are complex. Moreover, at wastewater treatment facilities, the concentrations of hazardous organics can vary by several orders of magnitude on a daily basis. Thus, the release of organics to the air or other media from bioremediation sites is difficult to estimate.

2) There is a correlation between operational experience with a biotreatment process and the state-of-the-art in modeling that proces. No models exist for some innovative new processes, such as the composting of hazardous materials. For some wastewater treatment processes, only models of substrate removal exist. On the other hand, many models have been developed to describe the fate of pollutants in some commonly used treatment processes, such as landfarming. Most of the models identified for this project are analytical models based on a mass balance approach. Some more complex numerical models also are reviewed.
3) Among the suspended-growth systems, a number of models have been developed to describe activated-sludge aeration tanks and surface impoundments. Biodegradation, adsorption, and volatilization and/or stripping are the removal mechanisms considered. Most of the models describe steady-state, completely mixed conditions. Few models of sequencing batch reactors or of powdered activated carbon treatment are available.
4) No models have been produced to simulate the emission of specific organic pollutants from fixed-film biologiical treatment systems. Most available models reflect a concern for substrate removal, in terms of biologocal oxygen demand (BOD). Under some conditions, estimates or measurements related to the mass transfer of oxygen can be used to approximate air emissions fom these systems.
5) Among soil-incorporation systems, land treatment facilities have been modeled most. The fate mechanisms included in the models include biodegradation, diffusion and volatilization, adsorption and solute transport. The models are non-steady-state and ouput is generated for specified times. No mathematical models exist to describe the composting of hazardous materials. One model simulates biodegradation of organic vapors in a soil treatment bed.
6) A number of models predict the fate of organic pollutants in the subsurface under natural conditions. The unsaturated-zone models are not designed to simulate *in situ* bioremediation, which often includes air sparging to stimulate microbial growth. While some of the saturated-zone models can be applied to *in situ* bioremedial efforts, they cannot be used to dirctly estimate air emisions. Pollutant vapors escaping from a contaminated aquifer must pass through the unsaturated zone. Thus, the likelihood and magnitude of air emissions from the saturated zone must be modeled using an unsaturated zone model with a pollution source term supplied at the water table boundary.
7) The biodegradation of organics in biological treatment facilities is poorly understood and limited data are available to estimate the biodegradation rate constants for compounds of interest. In addition, data generated in laboratories may vary greatly from field study data. Thus, reported values should be used with caution and experimentally verified when possible.
8) Suspended-growth system modeling results have been shown to be very sensitive to the values of the biodegradation parameters Thus, when accurate information about biological activity is not available, modeling studies should use a range of values, including zero, for the biodegradation rate constant By ignoring biodegradation, estimates of air emissions under "worst-case" conditions (e.g., periods of acclimation or of inactivity due to toxic shock) are obtained.
9) Most of the models summarized in this report have not been validated in the field. When predicted model results are compared to laboratory or field data, many authors report agreement within an order-of-magnitude. That level of agreement is generally considered adequate for screening purposes. Because of the many assumptions incorporated into the models, they should be used with caution for detailed site-specific studies.
10) To be able to adequately predict air emissions from biological treatment facilities, further research is needed in several areas. More collection of field data is needed, both in order to understand the severity of the problem and in order to aid in model development and validation. An improved understanding of the kinetics of biodegradation in multi-component heterogneous systems is needed. For some processes, first-generation fate models have yet to be developed. For other processes, the capabilities of the current models could be expanded.

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Gerard F Laniak is the EPA Project Officer (see below).
The complete report, entitled "Available Models for Estimating Emissions Resulting from Bioremediation Processes:A Review," (Order No. 90-228 610/AS;Cost $31 00 subject to change) will be available only from:
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United States Environmental Protection Agency
Research and Development

Atmospheric Research and Exposure Assesment Laboratory
Research Triangle Park NC 27711

EPA/600/S3-90/055

EPA Project Summary

Evaluation of an Anion Exchange Resin for Sampling Ambient Level Phenolic Compounds

Introduction

The currently available method for collection of vapor phase phenol and methylphenols involves aqueous sodium hydroxide impinger collection. Solution sampling is, in general, not practical for field sampling at remote sites; in addition, this impinger method has not been evaluated for collection of chemically diverse and more toxic phenolic species such as the chloro- and nitro-phenols. Sorbent based sampling methods are preferable to impinger methods. As an alternative to the impinger method, PUF (polyurethane foam)-Tenax-PUF sandwich sorbent cartridges have been evaluated recently for the collection of vapor phase chloro-phenols. While this method provides high collection efficiencies for the tetra- and pentachlorophenols, monochloro-phenols are not retained. These collection differences suggest that phenol and mono-functional phenols (e.g. methylphenols, nitro-phenols) also will not be retained by this sorbent.

The program described here was designed for evaluation of a solid sorbent, the anion exchange resin AG MP-1, for selective collection and retention of vapor phase phenolic compounds. The primary goal of the program was development of sampling and analysis conditions which would permit detection and quantification of diverse phenolic and hydroxylated species at ambient levels of 1 ppbv. The program also included 1) the development of methods for removing potential neutral interference compounds which could be retained by adsorption to the sorbent polymer backbone, 2) evaluation of stability of sorbent-bound analytes during prolonged storage, and 3) stability of sorbent-bound analytes toward nitration by ambient HNO_3. In addition, the program included preliminary field sampling evaluation of the sorbent. Field collection was carried out at two sites in northern Delaware; three additional samples were collected in the Columbus, Ohio area.

Anion exchange resins/sorbents are typically suspended in aqueous or organic media for chromatographic separations. For the strongly basic anion exchange resins, such as AG MP-1, the charge is fixed by the structure of the resin; positively charged quaternary amine groups are chemically bound to a styrene divinylbenzene lattice; the negatively charged counterion to the amine can be exchanged. The quaternary

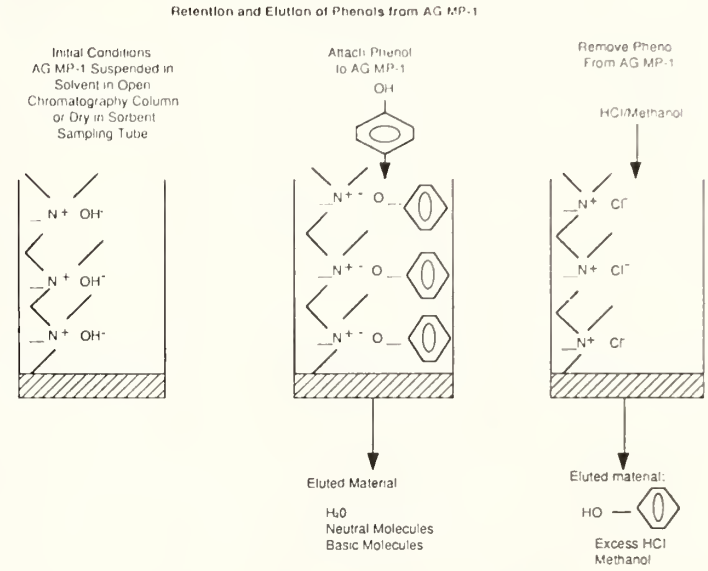


Figure 1. Schematic representation of collection of phenols with AG MP-1 and subsequent elution.

excessively during extraction of analytes with solvents and is not crushed easily during sampling and handling. The high degree of porosity allows retention of larger, less polar organic acids and phenols so as to increase contact time for formation of the chemical bond between analyte and quaternary amine. AG MP-1 is similar to the XAD-2 resins in physical properties such as ease of handling, mechanical strength, and color.

For sorbent sampling based upon adsorption, as with XAD-2, collection and retention are both described by chromatographic theory, the dominant factor being partition of analyte between gas and solid phase. For the anion exchange resin evaluated here, collection and retention are two separate issues. Phenols (and other acidic compounds) are retained on AG MP-1 by formation of a chemical bond; the reaction is reversed to liberate the phenols from the sorbent prior to analysis. Schematic representation of these steps is shown in Figure 1.

Experimental

For experiments conducted on this program, AG MP-1 was converted from the manufacturer-supplied Cl^- form to the OH^- form to obtain the strongest possible aqueous base (OH^-) for exchange. The OH^- on the resin will readily abstract a proton from phenolic and acidic organic analytes and

thus effect attachment of an analyte anion to the quaternary amine exchange site. Analyte anions are displaced from the resin later by application of an acid of greater strength than the analytes, in this case 2% conc. HCl in 15:85 (v:v) methanol:methyl-t-butyl ether. Under these conditions the Cl^- form of the resin is generated and the organic analyte is regenerated as a neutral molecule. Because formation of the chemical bond ensures retention of analytes, retention is the lesser important of the two considerations. Phenols will be retained unless sampling occurs in atmospheres of very high HNO_3 concentrations (or other acid whose pKa is less than that of the phenols of interest) where HNO_3 may either displace phenols from the sorbent or nitrate the phenols and, thus, form artifacts. Because of the dominant concern about collection, investigations here have centered upon those parameters which affect the formation of the initial chemical bond between phenolic analyte and sorbent.

Results and Discussions

Detailed presentations of results and relevant discussion are given in the full report for each laboratory and field experiment. For this summary, only highlights are presented for selected collection/recovery experiments; these are representative of the overall effort.

Based upon results from all of the laboratory tests, sorbent mesh size and superficial linear sampling velocity were those parameters which affected collection efficiency most dramatically. Sampling was most efficient with the 200-400 mesh AG MP-1 (particle diameter range of 38-75 µm) at a linear velocity of 1.75 cm/sec.

Recommendations

Based on the results of this study, sampling at 100 mL/min for vapor phase phenols may be applied best to air heavily impacted by specific emission/pollution sources. The method evaluated here may not provide sufficient sensitivity for ambient levels less than 1 ppbv. Therefore, the recommendations listed here are divided into two categories, those specific to the further evaluation and development of the sorbent sampler described here and those specific to development of a similar AG MP-1 based sampler compatible with higher sampling rates. It is recommended that further study of the following areas be performed:

Existing Method:

- Evaluation of the retention of vapor phase phenols by acid-washed glass fiber and quartz fiber filters.
- Evaluation of the components of laboratory AG MP-1 method blanks, with particular emphasis on phenolic and acidic species.
- Evaluation of extraction procedures which ensure complete recovery of phenolic/acidic analytes following extended (12-24 hr) sampling periods at 100 mL/min.
- Evaluation of the collection efficiency of AG MP-1 sorbent for phenols from very dilute gas streams.
- Further evaluation of stability of phenols and extraction efficiency from AG MP-1 following storage.
- Further evaluation of stability of phenols toward ambient levels of nitrating gases.

New Sampler (higher sampling rates):

- Development of an AG MP-1 based sorbent sampler for operation at 1-2 L/min and at 10-100 L/min to increase sensitivity.
- Development of an AG MP-1 based passive sampler with nominal sampling rate of 80-100 mL/min for fast sampling without electrical requirements.
- Evaluation of the anion exchange membrane AG 1-X8 (available from Bio-Rad; 90% AG 1, chemically similar to AG MP-1, incorporated into a polytetrafluoroethylene matrix) as an inlet filter on canisters or Tenax samplers.
- Evaluation of the anion exchange membrane AG 1-X8 as the inner surface of an anular denuder sampling system for determining phase distribution for the less volatile phenolic compounds.

Conclusions

The newly developed method for the determination of ambient phenolic compounds was successfully optimized and laboratory tested. Representative compounds exhibit an average collection/recovery of 89% for 1µg quantities sampled at 100 ml/min through the anion exchange sorbent AG MP-1. The method is a viable approach for trace-level determination of ambient phenolic compounds. Parameter testing and use of deuterated recovery standards indicate that further work is necessary to optimize sensitivity via sampler development (sorbent tube and pump-systems), and to further develop and optimize laboratory extraction procedures.

Marcia Nishioka and Hazel Burkholder are with Battelle Columbus Laboratories, Columbus, OH 43201.
***Joachim D. Pleil** is the EPA Project Officer (see below).*
The complete report, entitled "Evaluation of an Anion Exchange Resin for Sampling Ambient Level Phenolic Compounds," (Order no. PB90 246 091AS; Cost: $23.00 cost subject to change) will be available only from:
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650
The EPA Project Officer can be contacted at:
Atmospheric Research and Exposure Assessment Laboratory
U.S. Environmental Protection Agency
Research Triangle Park, NC 27711

United States
Environmental Protection
Agency

Atmospheric Research and
Exposure Assessment Laboratory
Research Triangle Park NC 27711

Research and Development

EPA/600/S3-90/054

EPA

Project Summary

Laboratory Method to Estimate Hydrogen Chloride Emission Potential Before Incineration of a Waste

Introduction

Current U.S. EPA regulations for permitted hazardous waste incinerators require analysis of the waste feed for total organochlorine content. At present, no adequate analytical method is known that will accomplish this. Furthermore, a method to measure hydrogen chloride emission potential in waste feed would be preferable since the purpose of the regulations is to control emission of HCl.

The current method assumes that organochlorine is the dominant source of HCl emissions from hazardous waste incinerators. Chlorine-containing organic molecules contain atoms of both elements required to form hydrogen chloride. For this reason, chlorine-containing organic compounds form HCl when burned in air.[1] Without a source of hydrogen, inorganic chlorides do not form HCl when heated to high temperatures in dry air. The result of heating an inorganic chloride to high temperature in the presence of a hydrogen-containing species (e.g., water) apparently has not been investigated in previous work.

The ultimate goal of the work described here is to develop a laboratory method to estimate, from analysis of a waste, the maximum amount of HCl that could form during incineration of that waste, regardless of the chemical environment of chlorine in the waste. The analytical approach chosen for evaluation involved heating a sample of chlorine-containing waste in a tube furnace, filtering particulate chloride from the hot gas stream, and trapping hydrogen chloride (HCl) gas by bubbling the filtered gas through water in an impinger. The collected HCl was measured as chloride (Cl^-) by ion chromatography (IC)/conductimetric analysis of the water solution.

Experimental parameters evaluated included the effect on HCl formation of (1) the bonding environment of chlorine in the waste, (2) the furnace temperature, (3) the presence of water vapor, and (4) the composition of the components of the furnace zone. A total of 35 experimental runs were conducted.

Experimental Run Procedure

Several initial runs using quartz components were conducted with the assembled apparatus to determine optimum sample size (actually, mass of chlorine which must be injected to obtain a reasonable percent recovery) and heat-tracing requirements. Wastes containing organochlorine, assumed converted completely to HCl when heated to 900°C, were used to monitor accuracy (percent recovery) as improvements were made in the apparatus and as the chlorine content of the waste and the injection volume were adjusted to achieve acceptable results.

Each experimental run consisted of (1) a single injection of a blank (referred to as the prerun blank), (2) three to five separate injections of the waste, and (3) a second injection of a blank (referred to as the postrun blank). The blanks were made up of the same matrix (ethanol and/or water) as the sample but contained no chlorine-containing species. The prerun and postrun blanks were used to monitor background concentrations of HCl. Each injection (waste or blank) generated a single liquid sample (collected in the first impinger) that was subsequently analyzed for chloride by IC with conductimetric detection.

The procedure used for each injection (waste or blank) into the laboratory apparatus is given in the full report.

Sample Preparation and Analysis

After volatilization and/or incineration of an injection of material (waste or blank), the deionized water in the first midget impinger was analyzed for chloride on a Dionex Model 14 ion chromatograph with conductimetric detection. Solutions to be analyzed were diluted, if necessary, to obtain a Cl^- concentration in the range of 0.06 to 15 ppm, the optimum working range for the measurement method. The conductivity meter had a detection limit of 0.01 ppm Cl^-.

Results and Discussion

A furnace tube and boat mechanism made of quartz were used for all prelim-

inary runs. The test atmosphere was 100% zero grade air and the temperature in the furnace zone was 900°C. Results of those runs appeared straightforward: Organohalogen was converted to HCl; inorganic chloride was not. Runs at 1000°C gave similar results.

A gas-mixing system was then added to the laboratory apparatus. It allowed the preparation of a test atmosphere containing a small amount of propane (0.5%) in zero grade air. Under the new conditions, 30-50% of inorganic chloride was converted to HCl.

Other hydrogen sources were then considered because of the safety hazards associated with handling propane. Water vapor was the obvious choice. Approximately 40% of inorganic chloride heated in an atmosphere containing water vapor was recovered as HCl. The presence of large amounts of HCl gas was confirmed by gas-filter correlation infrared spectroscopy (HCl analyzer). Likewise, IC analysis of an impinger solution from a laboratory run with a sodium chloride waste indicated 52.7% recovery of Cl^- as HCl, whereas analysis of the same solution by inductively coupled argon plasma indicated only 3.8% recovery of Na^+.

Addition of water vapor to the test atmosphere led to problems with degradation of quartz components. The boat was a brownish-red at the end of the ferric chloride runs presumably because of the presence of iron in the degraded quartz. This provides additional evidence that metal cations may remain, perhaps as silicates, on the walls of the tube and boat following conversion of chloride to HCl.

A furnace tube and boat made of INCONEL 600 (76.0% nickel, 15.5% chromium, and 8.0% iron) were used to determine if HCl formation was affected by the chemical composition of the tube and boat. Consequently, experimental runs with synthetic and real-world wastes were repeated with INCONEL components.

Conclusions

The results of this study have shown that formation of hydrogen chloride from incineration of a waste depends upon (1) the chemical bonding environment of chlorine in the waste, (2) the presence of hydrogen in the test atmosphere, and (3) the composition of the walls and other surfaces in the furnace zone.

In a quartz tube, organochlorine tends to be completely converted to HCl and does not require an external source of hydrogen. Heating of the organochlorine compound in an INCONEL 600 tube gave no measurable amount of HCl in the collection impinger. Ionic inorganic chloride is not converted to HCl, in quartz or INCONEL 600, unless a source of hydrogen (e.g., water vapor) is present. Ferric chloride results more closely resemble those obtained with organochlorine than those obtained with very ionic chlorides.

The presence of hydrogen (from water vapor) increased conversion of inorganic chlorine to HCl. This was true with both quartz and INCONEL components in the tube furnace.

Recommendations

The purpose of this method development activity was to develop a procedure that would allow estimation of the release of HCl during incineration of a hazardous waste feed stock. This project showed that such a method is impractical since the conversion of inorganic chlorine-containing compounds to HCl is incomplete and variable. Accordingly, it is recommended that the Agency can estimate the maximum hydrogen chloride concentration either by assuming total conversion of both organic and inorganic chlorides to HCl or by making a direct stack gas measurement.

To measure the acid gas control device efficiency an emission test both before and after the scrubber will be needed, because estimates of the maximum hydrogen chloride emission from feed data will lead to overestimation of scrubber efficiency.

Many additional studies could be performed to better define the parameters affecting the conversion of chlorides to hydrochloric acid. Experiments on pilot and full-scale incinerators would be interesting and potentially useful to regulators as well as those regulated. It is currently thought, however, that the conversion process is probably sensitive to enough parameters that accurate quantitative prediction by any test method is unlikely.

References

1. Peterson, M. R., Gaskill, A., Jr., and Jayanty, R. K. M. Total organohalogen (Phase I). EPA Contract Number 68-02-4442, Work Assignment 41, Research Triangle Institute, Research Triangle Park, North Carolina, 1988. 16 pp.
2. U.S. EPA, Method 0010, Test methods for evaluating solid waste, Vol. II field manual, physical/chemical methods, 3rd. ed. EPA-SW-846. U.S. Environmental Protection Agency, Washington, DC, 1986. 35 pp.

Max R. Peterson John R. Albritton, and R. K. M. Jayanty are with Research Triangle Institute, Research Triangle Park, NC 27709.

***Robert G. Fuerst** is the EPA Project Officer (see below).*

The complete report, entitled "Laboratory Method to Estimate Hydrogen Chloride Emission Potential Before Incineration of a Waste," (Order No. PB 90-235 854/AS; Cost: $15.00, subject to change) will be available only from:

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650

The EPA Project Officer can be contacted at:

Atmospheric Research and Exposure Assessment Laboratory
U.S. Environmental Protection Agency
Research Triangle Park, NC 27711

NIST Technology Update

National Institute of Standards & Technology
U.S. Department of Commerce, Gaithersburg, MD 20899

Materials Can Help Evaluate Industrial Atmosphere

Regulatory agencies and others studying the toxic metal concentration of industrial environments now have a new tool to help them achieve the most accurate measurements possible. It is a series of cellulose filters - similar to the ones used to sample atmospheric specimens - each containing certified concentrations of nine metals known to be toxic at certain levels. The filters that make up this standard reference material (SRM) can be dissolved easily in acid and diluted with distilled water to the desired volume and concentration level. In solution form, the SRM can be used in atomic absorption, optical emission (plasma), spectrometry, spectrophotometry, or any other analytical techniques that require aqueous (water-based) standard solutions for calibrating instruments. Metals represented on each of the filters are barium carbonate, cadmium, chromium, iron, magnesium, nickel, lead, selenium, and zinc. Each SRM consists of six filters containing the metals and five "blank" filters that allow chemists to assess the ambient levels of the metals being measured.

FOR ADDITIONAL INFORMATION: SRM 3087, Metals on Filter Media, sells for $155 and is available from the Standard Reference Materials Program, Rm. 215 Bldg. 202, NIST, Gaithersburg, Md. 20899; 301/975-6776.

Manufacturing, Machinery & Tools

0060 Bellows-Sealed 1/4-Turn Ball Valves (Licensing Opportunity)

0061 Method for Controlling Gas Metal Arc Welding (Licensing Opportunity)

0062 Product Data Exchange Specification (PDES) Organization

0063 Advances in Research on Powder Metal Manufacturing

0064 Checking Automated-Welder Programs by Computer—A personal-computer-based system, distinct from the welding-control computer, finds software errors

0065 Controlled-Pinch Spot Welder—Compressed air furnishes repeatable clamping force.

0066 Damping Seals and Bearings for a Turbomachine—Bearing loads are reduced to prolong service lives. (Licensing Opportunity)

0067 Milder Etchant for Penetrant Inspection—The etchant does not introduce artifacts that can be mistaken for defects. (Licensing Opportunity)

0068 Rolling Spot Welder—A wheeled tool speeds tack-welding operations.

0069 Simple, Internally Adjustable Valve—An adjustable orifice is made from two allen setscrews and an ordinary fitting.

Testing & Instrumentation

0070 Monitoring Both Sides of a Weld in Progress—Ultraviolet sources and cameras with image intensifiers would function despite brilliant arc light. (Licensing Opportunity)

0071 Monitoring Coating Thickness During Plasma Spraying—High-resolution video measures thickness accurately without interfering with the process.

Other Items of Interest

0042 Microbubble Flotation Development Unit

0076 Advanced Composite Pistons—Three-dimensional knitted fiber would yield improved mechanical properties. (Licensing Opportunity)

0080 Process for Autoclaving HMW PMR-II Composites—The qualities of autoclaved parts are equivalent to those of compression-molded parts.

0081 Making Self-Lubricating Parts by Powder Metallurgy—Thick parts can be made with minimal waste. (Licensing Opportunity)

0082 Shadow Moire Out-of-Plane Interferometric Damage Detector

Department of Energy

Technology Application

Idaho National Engineering Laboratory

Bellows-Sealed 1/4-Turn Ball Valves

Valve stem leakage can be a serious problem with industrial facilities that handle radioactive and hazardous liquids. Most valve stem seals consist of the valve shaft against an elastomeric seal that is vulnerable to wear and corrosion. Metallic bellows are used in valves where zero leakage is required. This invention allows a standard metallic bellows to be used in conjunction with a 1/4-turn valve. One end of the bellows is sealed to the valve shaft and the other end to the valve body. The shaft can move in a linear motion relative to the valve and can maintain a hermetic seal. The novelty of this invention lies in mechanisms to translate linear to rotational motion and to allow the 1/4-turn valve to be actuated by a standard push-pull type actuator.

Potential use would be in chemical processing, aerospace, nuclear, and petroleum industries. It would find application where high-reliability valves are needed to meet zero-release guidelines.

Laboratory Name: Idaho National Engineering Laboratory.

Reference No.: doe-inel-053.

Patent Status: Patent pending. Available for licensing.

FOR ADDITIONAL INFORMATION: Campbell, R.R., Executive Vice President, Westinghouse Idaho Nuclear Co., Inc., P.O. Box 4000, Idaho Falls, ID 83403; Telephone: FTS: 583-0997; Commercial: (208)526-0997.

Department of Energy

Technology Application

Idaho National Engineering Laboratory

Method for Controlling Gas Metal Arc Welding

The heat input and mass input in a gas metal arc welding process are controlled by a method that comprises (1) calculating appropriate values for weld speed, filler wire feed rate, and an expected value for the welding current by algorithmic function means; (2) applying such values for weld speed and filler wire feed rate to the welding process; (3) measuring the welding current; (4) comparing the measured current to the calculated current; (5) using said comparison to calculate corrections for the weld speed and filler wire feed rate; and (6) applying corrections.

This invention pertains to a method of controlling an automated welding process.

Literature: Smartt et al., "Gas Metal Arc Process Sensing and Control," *Advances in Welding Science and Technology* ASM International, (1986).

Laboratory Name: Idaho National Engineering Laboratory.

Reference No.: INEL-DOE-059.

Patent Status: U.S. Patent No. 4,825,038. Available for licensing.

FOR ADDITIONAL INFORMATION: Streier, G.G., Manager, ORTA, EG&G Idaho, Inc., P.O. Box 1625, Idaho Falls, ID 83415-3561; Telephone: FTS: 583-6042; Commercial: (208)526-6042.

Navy Manufacturing Technology

Automated Manufacturing Research Facility

National Institute of Standards & Technology
U.S. Department of Commerce, Gaithersburg, MD 20899

Product Data Exchange Specification (PDES) Organization

INTRODUCTION

In 1988 a group of major technology companies formed a corporation called PDES, Inc. to accelerate the development and implementation of the Product Data Exchange using STEP (Standard for the Exchange of Product Model Data).

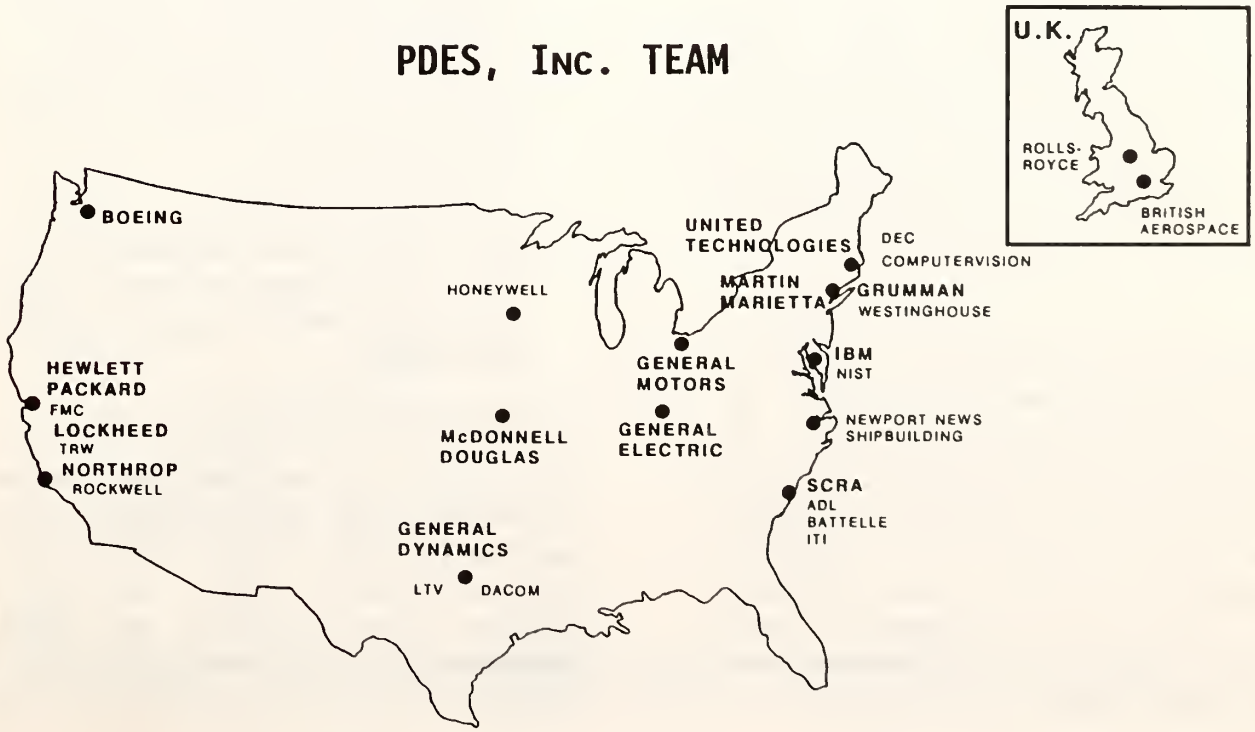
SOLID PROGRESS MADE

PDES, Inc. has made substantial progress in its first two years of operation. Its membership is now twenty three companies, including many of the country's largest (See Chart).

PDES, Inc. member companies commit technical and financial support to the organization on an annual basis. In return, members gain technical experience and receive valuable software tools that help them develop and implement prototypes of PDES applications. PDES, Inc. is managed by the South Carolina Research Authority (SCRA).

TECHNICAL/PROGRAM SUPPORT

Subcontractors provide technical and program management support to PDES, Inc. technical teams. The National Institute of



Standards (NIST), using DoD funding, is also a strong contributor. NIST has set up a major test bed at their Gaithersburg, Maryland, facility to support the validation of PDES, Inc. models. A development lab has also been established at SCRA.

PDES, Inc. has established effective coordination with the Initial Graphics Exchange Specification (IGES)/PDES Organization (IPO), the Navy Rapid Acquisition of Manufactured Parts (RAMP) Program, Sandia Laboratories and the Government Interagency Users Group.

RISKS IDENTIFIED

When PDES, Inc. was initiated, both technical and management risks were identified, including:

- Lack of a methodology or model for testing,
- Dispersion of resources, and
- Limited funding.

Innovative means of resource management, technical communications and risk reduction have been developed to address these challenges. For example, SCRA implemented an electronic network and bulletin board that ties members together through PCs and telephone links. In this way, timely information is distributed quickly to the diverse enterprises. High speed modems allow deliverable software developers easy remote access to testbeds.

TEAMWORK KEY SUCCESS ELEMENT

Teamwork has been the key to success for PDES, Inc. Dedicated members have tackled the problems of testing and evaluating the PDES Model by developing an application specific Context-Driven Integrated Models (CDIMs). The testing methodology provides for interrogation of these models against test requirements established by member company experts.

CHALLENGE IS TO IMPLEMENT A COMPLETE STANDARD

The challenge is to develop a strategy that effectively expedites the implementation of PDES as a complete standard. A revised implementation plan was approved by the Board this past February which will allow PDES, Inc. to foster such advancements.

SHEET METAL PROJECT

The first of these new projects is the development of sheet metal related CDIMs. The purpose of this project is to work with the IPO to draft an international standard for sheet metal parts, in-process part data and associated tooling to:

- Facilitate data sharing environments,
- Reduce costs,
- Improve quality, and
- Reduce time to market.

Significant support for this project is coming from the automobile industry.

PDES SEEKING NEW MEMBERS

PDES, Inc. membership facilitates being able to:

- Influence the implementation of emerging U.S. and international Standards,
- Obtain hands-on experience using the developing standard,
- Leverage resources, and
- Gain a head-start in preparing for the Government's Computer-aided Acquisition and Logistics Support (CALS) requirements.

FOR MORE INFORMATION

More information on PDES, Inc. can be obtained from Mr. Robert Kiggans of the South Carolina Research Authority, Trident Research Center, 5300 International Boulevard, North Charleston, S.C. 29418, telephone (803) 760-3219 or (803) 760-3250 (FAX).

Navy Manufacturing Technology

Automated Manufacturing Research Facility

National Institute of Standards & Technology
U.S. Department of Commerce, Gaithersburg, MD 20899

Advances in Research on Powder Metal Manufacturing

NIST is applying control paradigms developed for the Navy-sponsored AMRF for use in the Supersonic Inert Gas Metal Atomization (SIGMA) manufacturing process.

SIGMA produces ultra-fine rapidly solidified metal powder (<45 micrometers median particle diameter) using high-energy gas atomization. Metal powder is used in near-net shape production techniques in which the powder is consolidated into component parts that require little or no metal cutting.

Research at NIST on SIGMA has focused on acquiring process control knowledge through experimentation and process modelling, devising new manufacturing and sensing instrumentation, and developing an automated control system capable of performing the minute regulatory functions as well as higher level production objectives. The NIST researchers have determined optimal operating parameters by modelling the gas-molten metal interaction at the liquid delivery nozzle exit. This result has proven to be very effective in producing particles of a desired size distribution.

An important requirement for on-line process control is rapid acquisition of product quality information. Due to operating conditions, it is not feasible to measure particle size directly. Instead, a non-intrusive particle sizer instrument is used which measures the light scattered by the particles passing through the instrument's laser beam. NIST researchers are using an adaptive pattern recognition technique based on the principle of neural computing to transform light scattering distributions into particle size distributions. Performance of this technique exceeds all other known particle analysis methodologies.

The researchers also have developed a software tool which allows rapid prototyping of control system configurations. The tool permits the operator to specify process variable displays such as strip charts, scope charts, thermometers, dials, tanks, etc. as well as process instrumentation actuators such as toggles, sliders, and push buttons. The operation can be performed completely by manual control or can be automated using the real-time expert-system capabilities. The control strategy is encoded using typical data-driven and goal-driven constructs. Process variables can be accessed and instruments can be actuated within the knowledge-bases. The knowledge-base uses an object-oriented approach and individual knowledge-base "modules" can communicate via message passing.

The research on SIGMA has been conducted within the framework of a consortium consisting of various NIST groups and three private industry companies. The project is currently at the end of the first three year phase. Planning is being carried out to pursue further some of the more promising aspects of the research.

FOR ADDITIONAL INFORMATION: For further information contact: Stephen A. Osella, Bldg. 220, Room A127, AMRF Project, National Institute of Standards & Technology, Gaithersburg, MD 20899; (301)975-4263.

NASA Tech Brief
National Aeronautics and
Space Administration
Marshall Space Flight Center, Alabama

Checking Automated-Welder Programs by Computer

A personal-computer-based system, distinct from the welding-control computer, finds software errors.

A computer system detects and displays actual and potential errors in programs for a computer-controlled electron-beam welder. Such programs occasionally contain errors that are not detected by the control computer itself. The programs are usually complex and long and must be checked for programming errors by at least two people. The programs must be further validated in full-power tests in the welding vacuum chamber — a procedure that takes 2 to 3 hours, including setup time. Even with all this checking and with built-in safeguards, it is still possible for a program error to go undetected and cause damage to the parts being welded.

The new checking system uses a personal computer, which is separate from the welding computer. The system is programmed specifically to highlight errors in a welding program. It eliminates the need for the preweld full-power test run and thus reduces checkout time to about half an hour. At the same time, the system assures much higher quality, damage-free welding.

In addition to the personal computer with dual disk drives, the system includes a color monitor, a multipen plotter, a paper-tape reader and punch, and a dot-matrix printer. The personal computer analyzes a welding program for proper syntax. Possible syntax errors are displayed and printed out for the programmer's review. The computer also produces an event-time analysis to ensure that welding operations have the proper durations. It draws a multicolor graph on the plotter, showing welding parameters for each step in the welding sequence. Any step can be isolated and plotted on an expanded scale for close scrutiny. With these plots, the programmer can spot such nonsyntax errors as improper welding speeds or beam currents.

The final corrected program is punched on tape for use by the welding machine. It is also stored on a disk for future recall and modification. The parameter plot and a printout of the event-time analysis are stored with the disk for future reference.

The personal computer system can also be used to create and edit new programs for the welder. The control computer is thereby freed for production.

The system may also be useful for checking programs for such other computer-controlled equipment as inertia welders, robots, machine tools, and heat treaters. The system could also be extended to display, on the color monitor, a plot of process parameters as they actually occur, superimposed on a display of the programmed parameters. Deviations in the process would thus be immediately evident.

This work was done by L.O. Damicone of Rockwell International Corp. for **Marshall Space Flight Center.**
MFS-29006/TN

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama

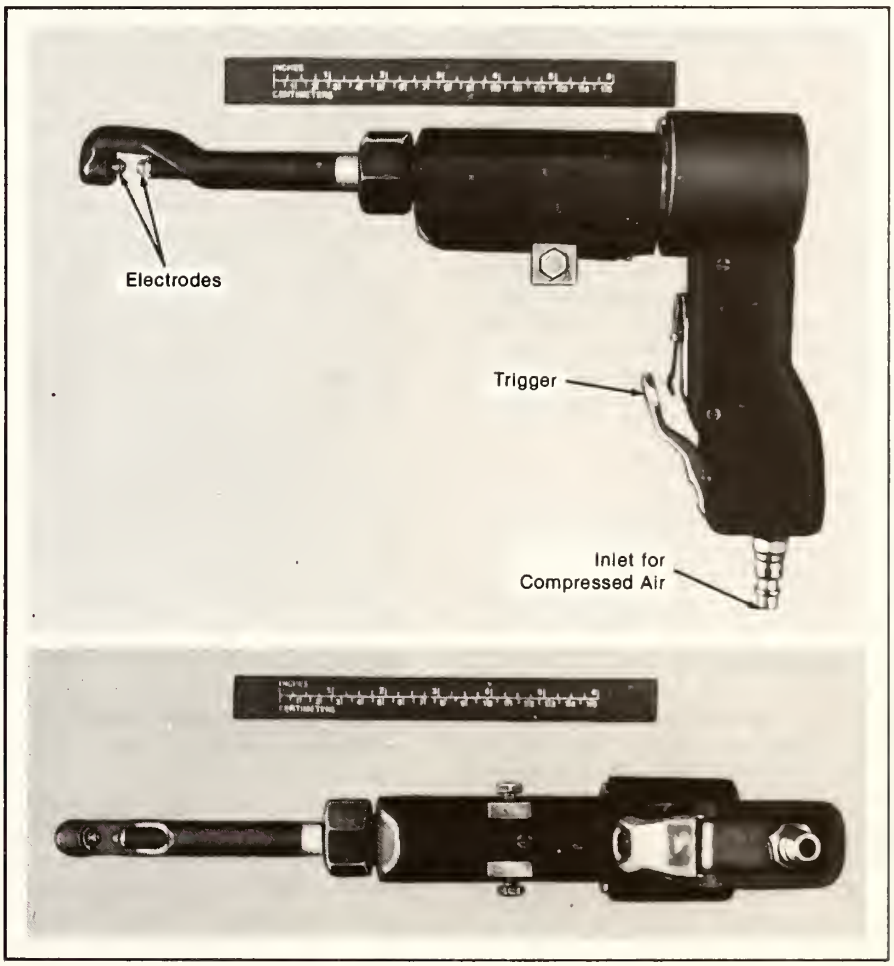
Controlled-Pinch Spot Welder

Compressed air furnishes repeatable clamping force.

A handheld spot-welding gun clamps the workpiece under air pressure instead of under the operator's hand pressure. It therefore makes spot welds that are more repeatable and reliable. It reduces the amount of manual labor required and enables welds to be made at a faster rate. Compact and light in weight, it can reach restricted areas that ordinary commercial welding guns cannot.

The spot-welding gun contains opposing pinching electrodes in a C-shaped tip (see figure). When the operator compresses the trigger on the handgrip, the air pressure drives the electrodes together so that they pinch the workpiece between them. Simultaneously, current flows between the electrodes and welds the workpiece. Shop compressed air, connected through a line to the heel of the handgrip, produces a uniform pinching force from weld to weld.

This work was done by Gene E. Morgan of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available.*
MFS-29606/TN



The **Trigger on the Handgrip** actuates both air pressure and welding current.

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama

Licensing Opportunity

Damping Seals and Bearings for a Turbomachine

Bearing loads are reduced to prolong service lives.

An improved design for the support of a rotor in a turbopump integrates ball bearings with damping seals and damping bearings. The new design reduces the radial (side) loads on the ball bearings, making it possible to increase the contact angles to withstand increased transient axial loads. As a result, the service lives of the bearings are prolonged.

The top part of Figure 1 illustrates one of the duplex sets of ball bearings. The outer races of the bearings are packaged tightly in one sleeve. A flange or web in the middle of the sleeve between the outer races applies the axial preload and prevents the outer races from spinning in the sleeve. The bore of the sleeve fits tightly [0.0005-in. (0.0127-mm) gap] against the outer races, while the outer sleeve surface has a generous gap of 0.004 in. (0.10 mm). The outer gap normally is kept open by the centering function of the damping-seal support or by the damping bearing.

The damping seal and the damping bearing have rather stiff fluid films [e.g., 1,000,000 lb/in. (175 MN/m)] that center the shaft, even under the high side loads at maximum operating speed. The floating sleeve radially unloads the duplex bearings, while the flexible suspension prevents the sleeve (and, therefore, the outer races) from spinning. These provisions help to prevent skidding of the balls and prolong the life of the bearing. The sleeves are attached to a soft [10,000 lb/in. (1.75 MN/m)] axial and radial spring. The soft spring centers the shaft during startup and shutdown, when the pressures are insufficient to maintain stiff fluid films in the damping-seal support and damping bearing.

Figure 2 illustrates one of the damping seals, which consists of an impeller rotor surface and a stator. The high differential pressure in the seal produces a stiff fluid film that acts as a bearing. The high stiffness is accompanied by high damping, which stabilizes the whirl at 90 percent of the speed of rotation of the shaft. The axial flow predominates because circumferential flow is intentionally hindered by isogrid pockets in the surface of the stator. Pressure losses at the inlet of the seal control the high seal-gap pressure, which produces radial stiffness and damping. The stiffness is amplified by the axial-flow gates in the walls of several upstream pockets. The gates spread the pressure surges to amplify the stiffness effect.

The bottom part of Figure 1 illustrates another set of ball bearings, between which the damping bearing discharges coolant directly into the inner races. The coolant follows the natural pumping of the balls. Radial struts hold the damping-bearing stator to the housing. The damping bearing carries the side load, while the duplex bearing package floats in a large gap [e.g., 0.004 in. (0.10 mm)]. The stator of the damping bearing has isogrid pockets on the inside bordering a smooth center dam. The rotor of the damping bearing is smooth, except for backward slanted nozzles. The nozzles are individually fed through radial holes from the bore of the shaft.

Pressure is added by centrifugal pumping in the radial holes. The pressure drop in the holes is optimally half the supply pressure to maximize the stiffness of the fluid gap. Swirling of the fluid reduces stiffness. Therefore, swirl is reduced by backward nozzles and the rough surface of the stator. The roughness also reduces leakage.

Stiffness is increased further by the axial gates through the walls of the pockets near the smooth center dam. The stiff damping bearing prolongs the life of the ball bearing by floating it.

This work was done by George L. von Pragenau of **Marshall Space Flight Center.**

This invention is owned by NASA, and

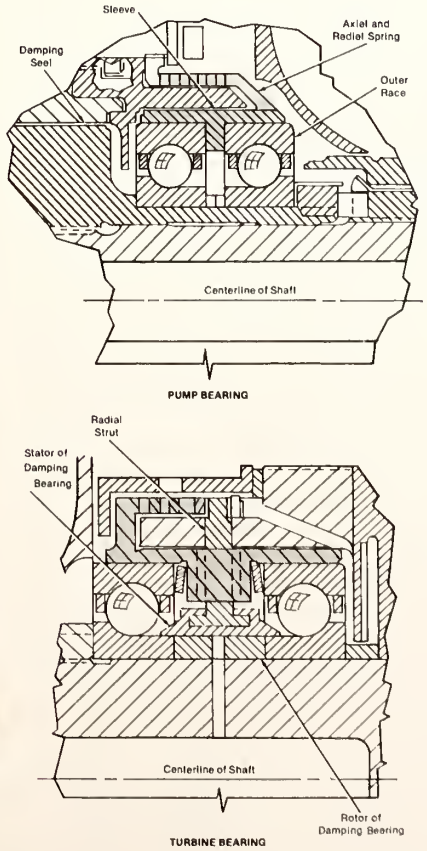


Figure 1. These **Duplex Ball Bearings** are designed for reduced side loading, and consequently, longer life.

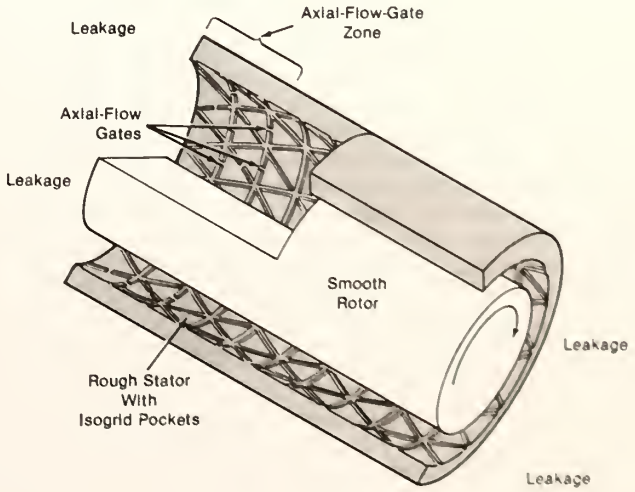


Figure 2. The **Film of Fluid** between the rotor and stator acts as a stiff bearing.

a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Marshall Space Flight Center. Refer to MFS-28345/TN.

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REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama

Licensing Opportunity

Milder Etchant for Penetrant Inspection

The etchant does not introduce artifacts that can be mistaken for defects.

The use of a new etching solution for chemical penetrant inspection of Inconel* 718 castings and weldments avoids ambiguous indications. A batch of the solution is composed of

250 g ferric chloride hexahydrate,
200 mL hydrochloric acid, reagent grade,
70 g oxalic acid, dihydrate, and
250 mL methanol, absolute.

It replaces a prepenetrant etchant, composed of 50 percent hydrochloric acid and 50 percent hydrogen peroxide, that tended to overetch, causing pitting and intergranular attack. After that penetrant is applied, such artifacts are difficult to distinguish from the original defects and, like the original defects, were unnecessarily removed by machining grinding.

The new etchant can be applied by swabbing or by immersion. The previous etchant was applied by swabbing the surface to be inspected; then if not removed after 10 to 30 seconds, any additional time is sufficient to overetch the material. In contrast, the dwell time for the new etchant is 120 to 180 seconds. The user therefore has more time to apply the solution thoroughly and prepare for penetrant inspection. Even when the dwell time is doubled over that recommended, there is no overetching. Moreover, because the new solution does not effervesce during application, the surface is not obscured, and the progress of the etch can be monitored visually.

The solution has a long shelf life. It can therefore be prepared in the laboratory under controlled conditions and stored until use, so that there need be no risk of incorrect mixing in the shop. The solution presents no hazards when used according to standard safety procedures. It can also be used to detect unwanted residues of Nioro* (or equivalent) gold brazing alloy on type 347 stainless steel.

*"Inconel" is a registered trademark of the INCO family of companies.

*"Nioro" is a registered trademark of WESGO Division, GTE Products Corp.

This work was done by Joseph E. O'Tousa and Clark S. Thomas of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center. Refer to MFS-29645/TN.

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NASA Tech Brief
National Aeronautics and
Space Administration
Marshall Space Flight Center, Alabama

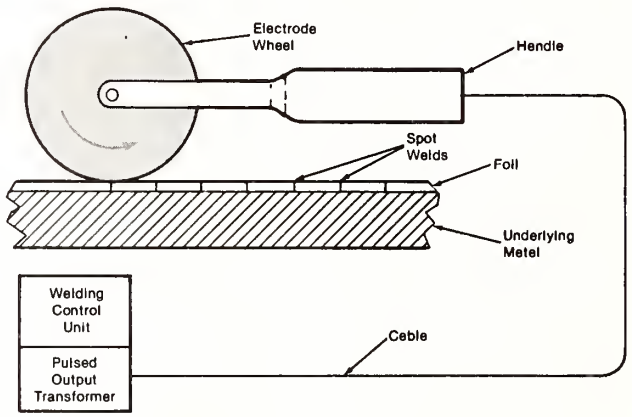
Rolling Spot Welder

A wheeled tool speeds tack-welding operations.

A tool spotwelds foil to parts in preparation for brazing. The tool, a slightly modified commercial product, includes an electrode wheel (see figure) that is rolled across the foil. The welding current in the electrode is pulsed as the electrode moves along, making a series of uniformly-spaced low-current spot welds.

Before using the tool, the technician makes a few spot welds manually. These welds prevent the foil from sliding when the wheel rolls over it.

In work on a large, complicated part (e.g., a rocket-engine nozzle, for which this tack-welding method was conceived), the use of the tool reduces the time spent in tack-welding operations by about 25 percent. It is anticipated that by integrating the use of the tool into a robotic tack-welding process, the time could be reduced by another 25 percent.



The **Control Unit and Transformer** send electrical pulses to the electrode wheel. The pulses tack-weld the foil to the underlying metal.

This work was done by Garret E. Wagner and Steve L. Fonteyne of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available.*
MFS-29580/TN

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama

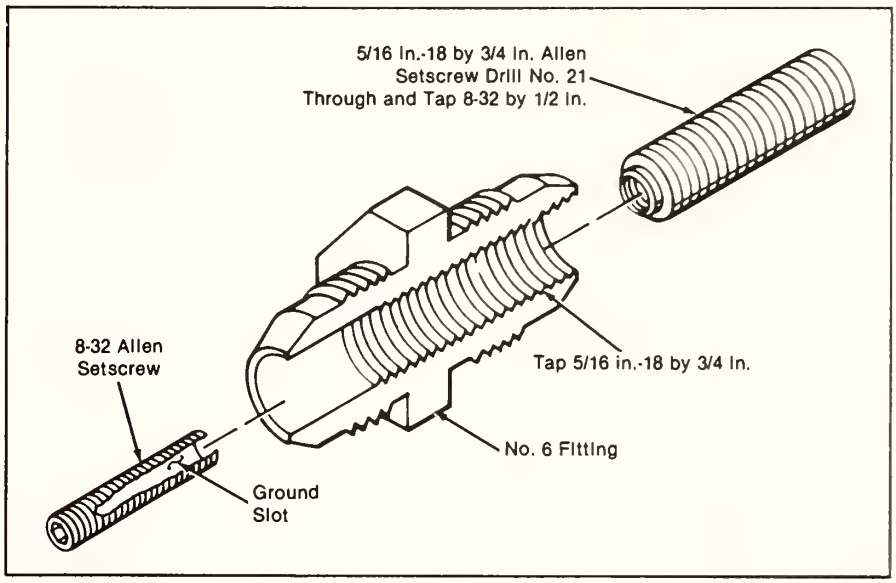
Simple, Internally Adjustable Valve

An adjustable orifice is made from two allen setscrews and an ordinary fitting.

A valve that contains a simple in-line, adjustable, flow-control orifice can be made from an ordinary plumbing fitting and two allen setscrews (see figure). The construction of the valve requires only simple drilling, tapping, and grinding. Often, the orifice can be installed in an existing fitting, thus avoiding changes in the rest of the plumbing.

The interior of the fitting is tapped to accept the larger of two allen setscrews. The larger setscrew is drilled along its axis and tapped to accept the smaller setscrew. A tapered slot is ground into the side of the smaller setscrew. The size of the orifice is controlled by turning the smaller setscrew in or out to adjust the amount of slot exposed.

To reach the inner allen screw to adjust the orifice, one of the two lines connected to the fitting must be removed. This may be an advantage in some applications, a disadvantage in others. The hidden, internal placement of the orifice reduces the likelihood of accidental or mischievous adjustment but makes frequent adjustment impractical.



The **Adjustable Flow-Control Orifice** can be installed in an ordinary plumbing fitting. The sizes and threads shown here are merely exemplary.

This work was done by Richard K. Burley of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available.*
MFS-29463/TN

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama

Licensing Opportunity

Monitoring Both Sides of a Weld in Progress

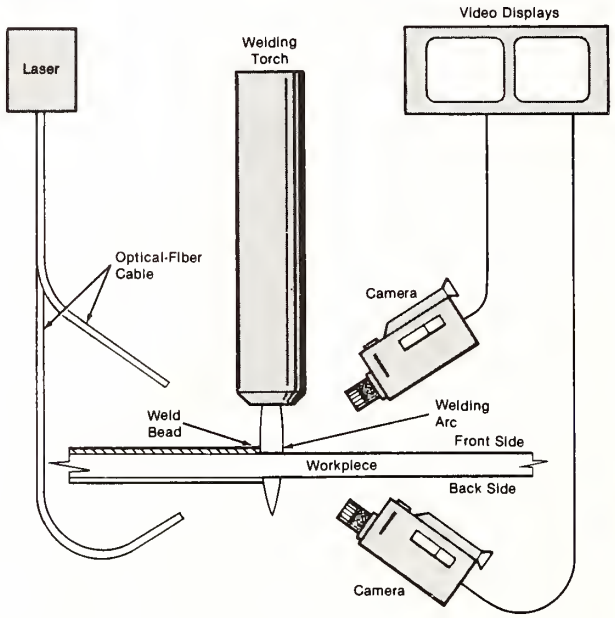
Ultraviolet sources and cameras with image intensifiers would function despite brilliant arc light.

A proposed remote vision system would provide for simultaneous viewing of the front and back of a workpiece while it is being welded. The system would thus enable a human or automatic controller to monitor both the weld pool on the front and the weld penetration on the back.

Because the intense light created by the welding arc makes viewing by visible light impractical, a nitrogen laser would generate ultraviolet light, which would be distributed to both sides of the workpiece through two optical-fiber cables (see figure). Image-intensifier tubes aimed at the weld on the front and back would convert the reflected ultraviolet light to visible light. Video cameras equipped with high-resolution charge-coupled devices would convert the visible outputs of the image intensifiers into images for viewing on video monitors.

This work was done by C. B. Dickinson and J. B. Hunt of Martin Marietta Corp. for **Marshall Space Flight Center**. *No further documentation is available.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center. Refer to MFS-28389/TN.



The **Dual-View Observation System** would look at both sides of a workpiece while it is being welded. Image intensifiers in the cameras would be sensitive only to ultraviolet light provided by optical fibers and therefore, would not be saturated by the intense visible light of the welding arc.

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NASA Tech Brief
National Aeronautics and Space Administration
Lewis Research Center, Cleveland, Ohio

Monitoring Coating Thickness During Plasma Spraying

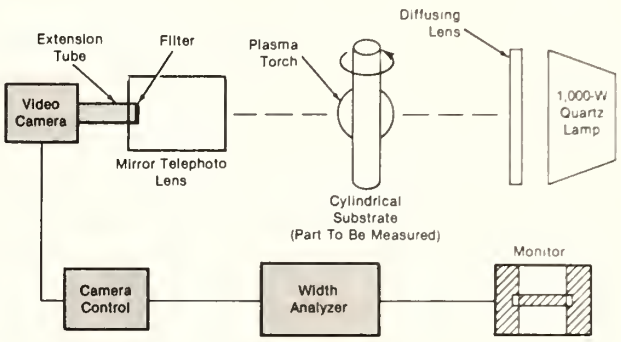
High-resolution video measures thickness accurately without interfering with the process.

A video system monitors the thicknesses of plasma-sprayed coatings. The system measures the thickness after each pass of the spray gun with the coated part in place; it is not necessary to interrupt the process to remove the part for measurement.

The incremental layer-by-layer measurements ensure that an adequate coat is built up without danger of exceeding the required thickness. The measurements also furnish information about the status of the process. If the process is well adjusted, the thickness increases linearly with the number of passes. A deviation from linearity could mean that process conditions need correction.

The system works best with parts that have simple shapes, like cylinders and plates. It can also be used at selected locations on more complex shapes. Its accuracy depends on the size of the part. It can measure the thickness of a coat on a 0.5-in. (1.27-cm)-diameter cylinder to within about 0.3 mil (0.008 mm).

The system (see figure) includes a commercial high-resolution video camera, a camera-control unit, and a width analyzer. The camera views the part from a distance of about 5 to 7 ft (1½ to 2 m) through a telephoto lens that has a focal length of 500 to 700 mm. A 1,000-W quartz lamp backlights the part so that the camera sees it in silhouette. A diffusing lens between the lamp and the specimen distributes light to provide a more-uniform bright spot.



The Camera Views the Cylindrical Part through a filter during plasma spraying. A lamp blacklights the part, creating a high-contrast silhouette on the video monitor. The width analyzer counts the number of lines in the image of the part after each pass of the spray gun.

The lamp appears brighter to the camera than does the plasma. Therefore, it is not necessary to use a shutter to protect the camera while the plasma flame is on, although a filter such as a number 6 welder's shade should cover the camera lens.

The field of view of the camera should encompass the entire thickness of the part. If the part is too large for this, then it must be held in position rigidly to prevent changes in position, which could give rise to errors in measurement.

The video monitor displays a negative, closeup image of the part. The width analyzer places the image of a bar over the image of the part and uses it to detect the number of white lines of the specimen contrasted against the black background. There are 1,024 lines available on the screen. For the 0.5-in. (1.27-cm)-diameter cylinder, magnified to cover about 75 percent of the width of the screen, one line represents about 0.33 mil (0.084 mm) of thickness. In practice, the resolution may be slightly better than this because fractional line widths can be estimated.

This work was done by Robert A. Miller of **Lewis Research Center**. *Further information may be found in NASA TM-101423 [N89-15218], Price Code: A02 "High Resolution Video Monitoring of Coating Thickness During Plasma Spraying."*

Copies may be purchased from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700. *LEW-14919/TN*

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

Materials

0072 Magnetostrictive Materials (Licensing Opportunity)

0073 Polyphosphazene Semipermeable Membranes (Licensing Opportunity)

0074 Technique for Producing High-Strength Copper Alloys (Licensing Opportunity)

0075 Galvanized Steel Coating Systems Tested

0076 Advanced Composite Pistons—Three-dimensional knitted fiber would yield improved mechanical properties. (Licensing Opportunity)

0077 Computing Deformations of Rubbery Materials—Better use is made of experimental data in finite-element computations.

0078 Directional Solidification of Monotectic Alloys—Conditions that promote the formation of aligned fibres are sought.

0079 Low-Noise, Long-Life, High-Gain Microchannel-Plate Glass—Dark noise is reduced substantially without degrading other properties. (Licensing Opportunity)

0080 Process for Autoclaving HMW PMR-II Composites—The qualities of autoclaved parts are equivalent to those of compression-molded parts.

0081 Making Self-Lubricating Parts by Powder Metallurgy—Thick parts can be made with minimal waste. (Licensing Opportunity)

Testing & Instrumentation

0082 Shadow Moire Out-of-Plane Interferometric Damage Detector

0083 Holographic Reticle—This device could be used for noncontacting, nondestructive inspection of surfaces.

Other Items of Interest

0054 Ultrasonic Monitor to Determine Crack-Opening Load—Harmonics of acoustical signals are generated by cracks.

0063 Advances in Research on Powder Metal Manufacturing

0086 Porous Elastomer for Use in Vascular Grafts, Artificial Organs, Permeable Drug Delivery Systems, and Other Uses

0096 Behavior of Evaporating Liquid Drops in Clusters—Progress in understanding combustion of sprayed fuels and related phenomena is discussed.

Department of Energy

Technology Application

Ames Laboratory

Magnetostrictive Materials

Ames Laboratory scientists have developed a new transducer material that produces mechanical motions by magnetostriction, improving upon conventionally used piezoceramic and electrostrictive materials. Applications for these magnetostrictive materials range from sonar and micropositioning devices to hydraulics, valve and fuel injection systems, and robotics. The new material, Terfenol-D, is fabricated by directional solidification, whereby Terfenol crystals align themselves parallel to the axis of the rod. This process produces near the maximum possible 1 values in this material. The 1 values are in the range of 1700 to 2000 ppm and are the largest for any known material at room temperature and above. Unlike piezoelectric transducers, which have high electrical impedances at low frequencies, Terfenol-D is ideal for producing powerful mechanical vibrations below 1 kHz. Users of Terfenol-D do not have to contend with the very high electric fields that can cause arcing in piezoceramic and electrostrictive devices. At room temperature, the length of a 10-inch rod of Terfenol can grow by .020 inches in microseconds when practical fields are applied. Such strains are {approximately} 40 times greater than magnetostrictive materials such as nickel, and {approximately} 10 times greater than conventional piezoelectric materials such as PZT. Terfenol-D responds within microseconds; the conventional lag times found in a mechanical system are reduced. Terfenol-D changes its shape due to atomic forces and can accommodate tremendous loads; strains of over 2000 ppm are achievable. With Terfenol-D, the conversion of electrical energy to mechanical energy occurs efficiently, with magneto-mechanical coupling factors greater than 0.7. It transmits extraordinary amounts of energy per unit volume. Its high-energy density leads to size and weight reductions of transducer elements. Terfenol has a potential impact on industrial processing and control for commercial and military sectors.

These materials can be used for sonic and ultrasonic applications, active structures and robotics, and power transmissions.

Literature: J.D. Verhoeven, E.D. Gibson, O.D. McMasters, and H.H. Baker, *Metallurgical Transactions*, Vol. 18A, pp. 223-231, 1987.

Laboratory Name: Ames Laboratory.

Reference No.: AL-89-05.

Patent Status: U.S. Patent No. 4,609,402; U.S. Patent No. 4,770,704; and U.S. Patent No. 4,849,034. Licensed to Edge Technologies, Inc., Ames, IA.

FOR ADDITIONAL INFORMATION: Williams, D.E., Office of Research and Technology Application, Ames Laboratory, 119 Office and Laboratory, Iowa State University, Ames, Iowa 50011; Telephone: Commercial: (515)294-2635.

Department of Energy

Technology Application

Idaho National Engineering Laboratory

Polyphosphazene Semipermeable Membranes

The principle application of prior art membranes has been in water desalination where the environment is relatively benign. Other applications such as petrochemical separations in mineral processing, in catalytic reactions, and in environmental cleanup, among a few, require use of a membrane in harsh environments such as strongly caustic or acidic solutions or high-temperature environments. A semipermeable, inorganic membrane is disclosed. The membrane is prepared from a phosphazene polymer and, by selective substitution of the constituent groups bound to the phosphorus in the polymer structure, the selective passage of fluid from a feedstream can be controlled. Resistance to high temperatures and harsh chemical environments is observed in the use of the phosphazene polymers as semipermeable membranes.

This technology may be used in environmental cleanup, mineral processing, and petrochemical separations.

Laboratory Name: Idaho National Engineering Laboratory.

Reference No.: DOE-INEL-060.

Patent Status: U.S. Patent No. 4,749,489. Available for licensing.

FOR ADDITIONAL INFORMATION: Streier, G.G., Manager, ORTA, EG&G Idaho, Inc., P.O. Box 1625, Idaho Falls, ID 83415-3561; Telephone: FTS: 583-6042; Commercial: (208)526-6042.

Department of Energy

Technology Application

Ames Laboratory

Technique for Producing High-Strength Copper Alloys

Advanced technological products such as rocket motor casings or high-field magnets require materials that have both high strength and superior thermal and electrical conductivity properties. Ames Laboratory metallurgists have developed a remarkable copper alloy for such applications. Compared to the highest strength commercial alloy (copper-beryllium), the Ames Laboratory material maintains the same strength and has twice the electrical contacts in subway trains, and capacitors. The idea for a copper-niobium composite grew out of Ames Laboratory basic research studies. That research dealt with solidification characteristics of copper-niobium alloys and resulted in the development of consumable arc techniques for scaling up the process. The technique used for making the copper-niobium alloy involves the formation of an electric arc between an electrode made of copper and niobium and the cylinder into which the electrode melts. This process distributes the niobium uniformly in what is called a dendrite pattern. When the material has cooled, it is drawn down in size. This mechanical process has the effect of elongating the niobium material. The thinner and longer the filaments are stretched, the stronger the material becomes. The alloy recently was fabricated into wire by Supercon, Inc., of Shrewsbury, Massachusetts, and then used to build a new type of pulsed magnet for the National Magnet Laboratory at the Massachusetts Institute of Technology. The magnet broke all records by generating a magnetic field intensity of 68 Tesla.

This technique can be applied to requirements of both high strength and electrical conductivity, such as in electrical spring contactors, welding electrodes, rocket casings, high current magnet windings, and so forth.

Literature: J.D. Verhoeven, F.A. Schmidt, E.D. Gibson, and W.A. Spitzig, *Journal of Metals*, Vol. 38, Sept, 1986, pp. 20-24.

Laboratory Name: Ames Laboratory.

Reference No.: AL-89-06.

Patent Status: U.S. Patent No. 4,532,703; U.S. Patent No.4,600,448; and U.S. Patent No. 4,770,704.

FOR ADDITIONAL INFORMATION: Williams, D.E., Office of Research and Technology Application, Ames Laboratory, 119 Office and Laboratory, Iowa State University, Ames, Iowa 50011; Telephone: Commercial: (515)294-2635.

NAVY
Domestic Technology Transfer Fact Sheet

Galvanized Steel Coating Systems Tested

Since deterioration of organic coatings on galvanized steel is one of the most commonly encountered problems at naval shore activities, researchers at the Naval Civil Engineering Laboratory (NCEL), Port Hueneme, California, conducted an experiment to determine the factors contributing to the deterioration and how to obtain better coating performance. Variables included six surface treatments, two weathering variations, and five chemical compositions. The two coating properties measured were initial bonding to galvanizing and salt fog resistance. Significant conclusions were as follows:

- Wash priming improved the bonding strength of coatings to unweathered galvanizing and the salt fog resistance of coatings to both weathered and unweathered galvanizing. No other surface treatment was beneficial.
- Weathering of the galvanizing before coating generally reduced bonding but improved salt fog resistance.
- Using an epoxy-based composition performed best of all and did not require wash priming for good performance.
- Using zinc chromate primer improved salt fog resistance to an alkyd-based composition, but a zinc dust/zinc oxide primer did not.

For Additional Information:

Backup material on this effort is available from:

Navy Domestic Technology Fact Sheet Reader Reply Service
Code E211
Naval Surface Weapons Center
Dahlgren, VA 22448-5000
(703) 663-8921

Refer to 150303/TN

NASA Tech Brief
National Aeronautics and Space Administration
Langley Research Center, Hampton, Virginia

Licensing Opportunity

Advanced Composite Pistons

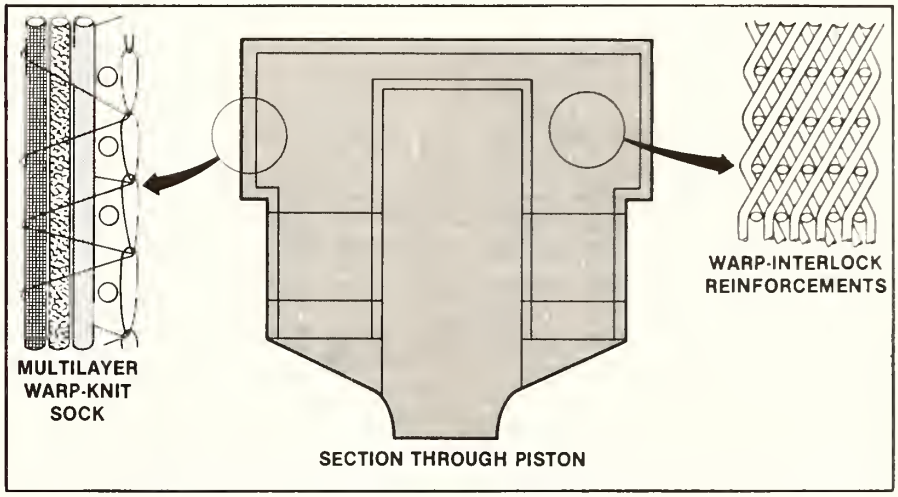
Three-dimensional knitted fiber would yield improved mechanical properties.

A new concept involving an improved configuration of reinforcing fibers and an improved fabrication process is proposed to improve the thermal and mechanical properties of composite piston structures. The concept reduces the amount of labor necessary to manufacture piston structures, with attendant reductions in costs.

At present, composite piston structures are made with omnidirectional fiber mat to form the basic piston shapes, and unidirectional or woven two-dimensional fabrics to provide selective reinforcements where added strength is required. Two-dimensional layups and uniaxial fiber reinforcements are inherently weak in interlaminar properties and are difficult to fabricate. Additional woven plies to increase thicknesses and reduce the intensities of loads, or cross-stitches to improve interlaminar strength, are required to attain the desired mechanical properties.

The new design involves the enhanced configuration, shown in the figure, wherein a single knitted-carbon-fiber structure with one end closed (a sock) is used to form the external surfaces of the piston. The areas requiring additional strength, such as the wristpin bosses and piston crown, are reinforced as necessary with three-dimensional woven or braided monolithic shapes or precut plies of two-dimensional fabric.

The knitted sock (preimpregnated with phenolic resin) is laid in a female mold, closed-end first, then the crown and wristpin-boss reinforcements (also preimpregnated) are positioned. The open end of the sock is then draped back over the local reinforcements to form the inner surface of the piston. Pressure is then applied to the laminate by use of an expandable male mold. While under pressure, the laminate is cured at 325 °F (163 °C) to form the desired piston shape. Alternatively, the layup can be placed over the expandable male mold and then inserted into the female mold to obtain the same result.



A **Single Knitted-Carbon-Fiber Sock** is used to form the external surfaces of the piston.

The preform is then subjected to an inert-gas pyrolysis treatment to carbonize the phenolic resin. It is then reimpregnated and repyrolized. The pyrolysis and infiltration steps are repeated to densify and strengthen the structure to attain the desired properties. These infiltration and pyrolysis steps are followed by a chemical-vapor deposition step, which provides an impervious carbon surface.

Among the advantages of this concept are improved mechanical properties of finished pistons and, especially, the elimination of heavy dependence on the inherently weak interlaminar properties of carbon-carbon; ease of automation to reduce fabrication costs; readily modifiable architecture to vary mechanical properties to desired values; and reduction in the number of elements required to fabricate pistons. The advantage of these piston structures lies in applications where light weight and high specific performance are the primary considerations.

This work was done by Allan H. Taylor and Philip O. Ransone of **Langley Research Center.**

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center. Refer to LAR-13926/TN.

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REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

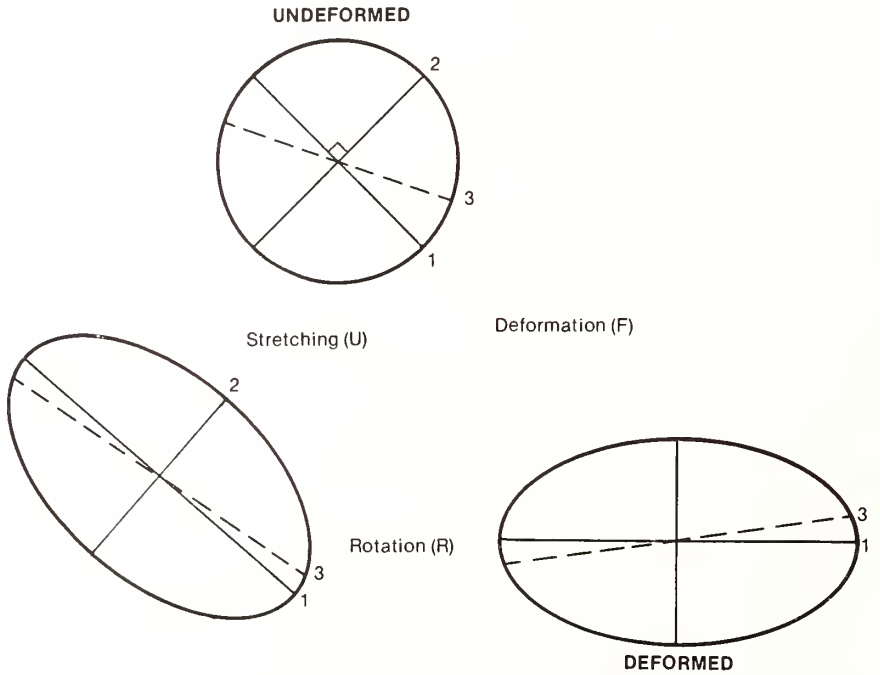
Computing Deformations of Rubbery Materials

Better use is made of experimental data in finite-element computations.

A new formulation of the constitutive equations of a rubbery, nonlinearly elastic material enables the finite-element analysis of boundary-value stress-and-strain problems that involve arbitrary shapes and loads. In the development of this formulation, principal stretches (as contrasted with the more traditional principal invariants of strain) are used as arguments of the strain-energy-density function. However, unlike in the traditional formulation, there is no need to calculate the strain-energy-density function explicitly in the application of this formulation to a specific load-versus-deformation problem. Instead, readily available experimental data on loads versus deformations, interpolated where necessary, are used in a more direct manner.

The change in shape, caused by elastic deformation, of the infinitesimal part of a body surrounding a particle that was at a specified reference position when the body was undeformed, can be expressed as a deformation gradient, *F*, that is the product of a rigid-body-rotation tensor, *R*, and a stretch tensor, *U*, that specifies principal stretches (or compressions). The figure illustrates the geometrical relationships among *F*, *R*, and *U*. In the traditional approach, a polynomial or other form of the strain-energy-density function is fitted to the experimental load-versus-deformation data, and stresses are calculated by taking the first and second derivatives of this function with respect to the strains. This procedure is disadvantageous in that the fitting function may not interpolate the experimental data accurately, and the inevitable noise introduced by the computation of derivatives increases the inaccuracy.

In deriving the new approach, the strain-energy density is initially expressed as a separable function, *w*, of the principal stretches. However, because only the values of the derivatives of the strain-energy-density function and not the form of the function are needed for the computation of stress, the function is manipulated into a form in which one can work with interpolated experimental data, calculating points on a curve that describes the response of the material. This approach provides for the most direct and straightforward use of experimental data in the solution of boundary-value problems.



The Deformation of Material in the vicinity of a point can be represented by stretching, which transforms a circle fixed to the material into an ellipse, followed by a rotation of the ellipse.

The constitutive equations based on the new formulation have been incorporated into a finite-element computer code, TEXLESP-S, which solves equilibrium problems for three-dimensional, incompressible, hyperelastic bodies. The code has been demonstrated by using it to analyze stretching of thin, biaxial test specimens by various amounts up to 90 percent.

This work was done by Steven T.J. Peng of Caltech and Eric B. Becker and Trent M. Miller of Becker and Miller for **NASA's Jet Propulsion Laboratory.**
NPO-17670/TN

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NASA Tech Brief
National Aeronautics and Space Administration

Directional Solidification of Monotectic Alloys

Conditions that promote the formation of aligned fibers are sought.

A report describes experiments in the directional solidification of Cu/Pb and Bi/Ga monotectic alloys. (A monotectic alloy is one in which the temperature-versus-composition phase diagram is characterized by a dome-shaped region in which two liquid metals are immiscible.) This study was motivated by the need to understand the physical mechanism that governs the formation of rodlike or fiberlike aligned structures in the solidifying alloy and to determine the process conditions that favor such structures.

In this study, samples of the alloys were directionally solidified both upward and downward in normal gravitation at various furnace-translation rates and temperature gradients. Similar experiments were performed in simulated low gravitation aboard a KC-135 airplane flying along a parabolic trajectory. Solidified specimens were cut along and across the axes of solidification, ground, polished, and photographed under both visible-light and scanning electron microscopes. Compositions were measured by x-ray microanalysis in the scanning electron microscope.

The hypomonotectic Cu/Pb alloys (those with nonimal Pb contents below the monotectic composition) were found to have solidified with equiaxed copper grains containing trapped intragranular lead. The absence of convection and sedimentation in low gravitation resulted in larger copper grains.

The formation of fibrous composite structure can be explained in terms of a version of a previously enunciated mechanism for the engulfment and pushing of particles. In a hypermonotectic Cu/Pb alloy, at a low speed of the solidification front, the lead droplets are apparently either pushed by the solidifying interface, occasionally becoming engulfed, or coalesce and form lead-rich bands. At a high speed, the droplets are apparently continuously engulfed to form fibers.

High gravitation was found to be more favorable than is low gravitation for the initiation of growth of fibers. However, once fibers have started to form, they continue to grow in low gravitation. The distances between fibers formed in low gravitation were slightly greater than those formed in high gravitation.

In the Bi/Ga samples, the dominant structure consisted of Ga-rich droplets in a Bi matrix. Short fibers grew only at very high rates of solidification. When the differences between the properties of Bi/Ga and Cu/Pb were taken into account, these observations were found to be consistent with the details of the theory of pushing and engulfment.

This work was done by B.K. Dhindaw, D.M. Stefanescu, A.K. Singh, and P.A. Curreri of the University of Alabama for **Marshall Space Flight Center**. *"Directional Solidification of Cu-Pb and Bi-Ga Monotectic Alloys Under Normal Gravity and During Parabolic Flight."*
MFS-26080/TN

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NASA Tech Brief
National Aeronautics and Space Administration
Langley Research Center, Hampton, Virginia

Licensing Opportunity

Low-Noise, Long-Life, High-Gain Microchannel-Plate Glass

Dark noise is reduced substantially without degrading other properties.

A glass suitable for use as the active material for microchannel plates (MCP's) is free of constituents that include significant amounts of radioactive isotopes. Background noise, or "dark noise," in well-outgassed MCP's that are free of hotspots is due largely to β radiation emitted by isotopes of constituents of glass. Although considerable research has been performed during the last several years and improved MCP's have been produced, background noise is still present, even in the best commercially available MCP's. Consequently, work was undertaken to produce a glass that has minimal intrinsic radioactivity and can be used to manufacture MCP's with electron gain, strip current, lifetime, and operating characteristics equivalent to those of the best commercially available MCP's.

This objective was accomplished by the formulation of glasses that have the following range of compositions, in weight percent:

SiO_2	30 to 35
PbO	50 to 57
Cs_2O	2 to 10
$\Sigma[MgO + CaO + SrO + BaO]$	0 to 5
$\Sigma[Al_2O_3 + ZrO_2 + TiO_2 + Nb_2O_5]$	0.1 to 1

where the mole ratio of SiO_2 to PbO is 2.0 to 2.4.

The ranges of proportions of SiO_2, PbO, and Cs_2O were chosen on the basis of estimates of the influences of these components on the properties of glasses. These ranges provide desired levels of glass-transition temperature, coefficient of thermal expansion, durability in acid, surface resistivity, softening point, and glass conductivity. These properties influence such factors as dimensional control and acceptable stress levels during production of the MCP, and attainment of appropriately high and stable strip currents for proper operation of the MCP. Alkaline earth elements, in the form of MgO and CaO, are incorporated to control forming viscosities and chemical durability. Al_2O_3, ZrO_2, TiO_2, and Nb_2O_5 are specifically incorporated to improve chemical durability.

Measurements of dark noise on a chevron pair of sample MCP's at ambient temperature (23 °C) have given a figure of 0.08 counts/(cm^2•s), one-eighth that of standard MCP's and one-third that of the quietest prior-art MCP's. However, this figure may also include residual radioactivity from non-MCP components in the test detector. Replacement of ceramic hardware, which is known to contain radioisotopes, is currently underway. Thus, the ultimate dark-noise figure of the MCP could be even lower.

This work was done by W. Bruce Feller and Lee M. Cook of Galileo Electro-Optics Corp. for **Langley Research Center**. *No further documentation is available.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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NASA Tech Brief
National Aeronautics and
Space Administration

Process for Autoclaving HMW PMR-II Composites

The qualities of autoclaved parts are equivalent to those of compression-molded parts.

Parts made of graphite-reinforced, high-molecular-weight (HMW) PMR-II polyimide are easy to fabricate by autoclaving, a study has found. The study, described in a 16-page report, showed that autoclaved HMW PMR-II parts are equal in quality to those made by compression molding. The PMR-II parts are well suited to use at temperatures up to 700 °F (371 °C). In aircraft engines, for example, they offer the advantages of strength and light weight.

The study was aimed at improving the processability of low-flow HMW formulations of PMR-II polyimides. The HMW PMR-II resins provide improved thermooxidative stability over low-molecular-weight formulations but are much less tractable and require high molding pressures.

The study resulted in the development of a new autoclave curing process for HMW PMR polymide composite materials. The process requires the use of high vacuum for consolidating the material before it advances to the intractable state and requires pressures of 200 psi (1.38 MPa) or less.

Graphite-fiber reinforced laminates were prepared with HMW PMR-II resin using both high-compression and autoclave fabrication processes. The laminates were isothermally exposed in the air at 650 °F (343 °C) and 700 °F (371 °C). After 500 hours exposure at 700 °F (371 °C), specimens lost only 8 percent of their weight, while specimens exposed longer than 750 hours at a lower temperature lost only 5 percent. All the exposed specimens retained greater than 90 percent of their original elevated-temperature flexural and interlaminar shear strengths.

This work was done by Raymond D. Vannucci and Diane Cifani of **Lewis Research Center.** *Further information may be found in NASA TM-100923 [N88-24712], Price Code: A03 "700°F Properties of Autoclave Cured PMR-II Composites."*

Copies may be purchased from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700. *LEW-14839/TN*

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NASA Tech Brief
National Aeronautics and Space Administration
Lewis Research Center, Cleveland, Ohio

Licensing Opportunity

Making Self-Lubricating Parts by Powder Metallurgy

Thick parts can be made with minimal waste.

Compositions and parameters of powder-metallurgical fabrication processes have been determined for a new class of low-friction, low-wear, self-lubricating materials. These materials can be used in oxidizing or reducing atmospheres (e.g., air or hydrogen, respectively) in bearings and seals, for example, at temperatures from below 25 °C to as high as 900 °C.

The new composites are derived from plasma-sprayed self-lubricating coating compositions previously developed at Lewis Research Center. Plasma spraying is unsuitable for making such thick or freestanding parts as bearings, bushings, valve seats, and gears. Plasma spraying also wastes material — an especially important consideration where precious metals are components of the compositions. Furthermore, in plasma spraying, it is difficult to control the composition of the deposited alloy because the different components have different deposit efficiencies.

A representative alloy of the new type is specified from among the following components and ranges of compositions:

- 30 to 70 weight percent of chromium carbide, hafnium carbide, or other carbide resistant to oxidation;
- 5 to 20 weight percent of soft noble metal, usually silver or gold;
- 5 to 20 weight percent of high-temperature solid lubricants, which consist of fluorides of metals of group I or II of the periodic table, fluorides of rare-earth metals, or mixtures of such fluorides; and
- 20 to 60 weight percent of a metal binder, which can be an alloy of nickel, cobalt, or both.

The component powders are blended in the desired proportions, then processed into parts by one or more powder metallurgical processes. For example, in one case cold mechanical pressing might be followed by cold or hot isostatic pressing, then by sintering. In another case, there might be a single step involving hot mechanical pressing. Typical processes and their parameters include the following:

- Cold mechanical pressing at a temperature of 25 °C and a pressure of 5 to 20 kpsi (35 to 140 MPa);
- Cold isostatic pressing at 25 °C and a pressure of 40 to 80 kpsi (280 to 560 MPa);
- Sintering at 900 to 1,200 °C for 10 to 30 min in hydrogen or inert gas at a pressure of 1 atm (0.1 MPa);
- Hot isostatic pressing at 900 to 1,200 °C, at a pressure from 20 to 60 kpsi (140 to 420 MPa); or
- Hot mechanical pressing at 900 to 1,200 °C, at a pressure from 20 to 60 kpsi (140 to 410 MPa), in an atmosphere of hydrogen or an inert gas.

This work was done by Harold E. Sliney and Christopher DellaCorte of **Lewis Research Center.**

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Lewis Research Center. Refer to LEW-14902/TN.

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Technology Fact Sheet
U.S. Air Force

Shadow Moire Out-of-Plane Interferometric Damage Detector

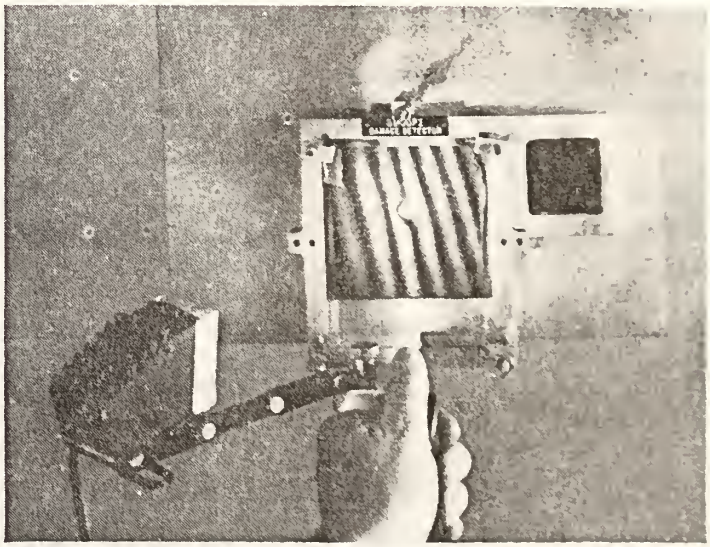
APPLICATIONS
Fielded: Naval Aviation Depots - Cherry Point, Norfolk and Alameda.

SYNOPSIS
The Shadow Moire Out-of-Plane Interferometric (SMOOPI) Damage Detector (pictured) is a portable, in the field, tool for detecting surface irregularities due to impact, delamination, and fatigue in laminated composites and honeycomb sandwich structures. SMOOPI has also been tested to detect surface irregularities in any material; irregularities due to cold-working in holes in metal structures and blistering in anti-corrosion paints. A variety of nondestructive methods are available; however, these methods can be tedious, time consuming and unreliable in field conditions where temperature, humidity and vibration can severely affect the results.

SMOOPI

Number: TT 90048

The device uses the basic principles of Shadow Moire Interferometry. Surface irregularities become visible in the form of Moire fringe patterns (pictured). The basic technique measures the interference fringes created by the superposition of two grids (system of finely ruled lines), one on the specimen and the other on a master grid or reference grid. In this case, the specimen grid is the shadow of the master grid on the specimen surface. The shadows are distorted by the out-of-plane elevation or depth of the surface (caused by surface defect) and when viewed through the master grid, produce fringes which are clearly visible.



MOIRE FRIGE PATTERNS

Structural surfaces are examined through a 4 X 5 inch frame that holds the master grid. The frame is placed in contact with and parallel to the surface to be examined. A quartz light source is used to illuminate the master grid and produce the shadow grid below. On a flat surface with no damage, a zero pattern without fringe patterns is observed. If, for example, there is spherically-shaped damage, then a fringe pattern of concentric circles will be observed.

BENEFITS/DRAWBACKS
The SMOOPI Damage Detector is small, light weight and is not affected by temperature, humidity variations, or vibrational disturbances. It can be used under field operational conditions with minimum training. The SMOOPI Damage Detector consists of an aluminum frame mounted on an extended pistol grip. Attachments are included for easy installation of a 4 X 5 inch Moire grid. The frame provides a .030 inch clearance between the grid (continued)

and the surface to be examined. A 35-watt quartz light source provides a collimating line source and is attached to the frame with a 6 inch support for simple adjustments of illuminator angle and vertical position. The light source can be powered by a rechargeable battery pack or a.c. adapter. The entire detector system fits into the size of a 35mm camera case and weighs less than 3.5 pounds.

A complete SMOOPI Damage Detector system costs $2000 to $3000. This is inexpensive when compared to the price of most ultrasonic equipment at $50,000 plus. Field organizations can afford multiple units at these low cost figures. In the near future the (improved) detector will be commercially available. Hopefully, this will reduce the cost to below $2000.

The SMOOPI Damage Detector was developed to detect surface perturbations of less than .001 inch. Sensitivity of the system is based on the selected illumination angle, grid density and the elevation or depth of the observed point. For surfaces with poor contrast, a white spray powder (Fluorofinder FD-33 Developer or equivalent) is used to increase contrast during inspection. The powder is easily cleaned from the surface after inspection.

Additional damage characterization may be necessary by other techniques. SMOOPI cannot detect damage below the surface unless the damage causes a surface irregularity. Also, surface irregularities of less than .001 inch may be overlooked. SMOOPI is ideally suited for inspecting large areas quickly to identify those areas needing further inspection. SMOOPI has proven useful in conducting in-between phase inspections, or where time is critical and no other inspection method is available.

AIR FORCE R&M 2000 GOAL HIGHLIGHTS

Increase Combat Capability:	Detect and repair damage before catastrophic failure causes downtime. Suspected aircraft damage can be inspected within minutes of landing.
Decrease Mobility Requirements:	Lightweight, highly portable inspection equipment. The item to be inspected does not have to be moved to special facilities or fragile expensive equipment brought to the field.
Decrease Manpower Requirements: (Per Unit of Output)	Faster method of inspection. Fully inspecting an AV-8B Harrier for composite damage with ultrasonic equipment usually takes weeks. SMOOPI reduces inspection time to a few hours.

DOCUMENTATION

Nondestructive Evaluation (NDE) of Delaminations, A. E. Scotese

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This TechTIP report was produced as part of the Technology Transfusion Opportunities Program at the Acquisition Logistics Division, Joint Technology Applications Office (ALD/JTT). Determining the feasibility of using this technology in a particular application requires a thorough evaluation of system requirements and the capabilities provided by the technology. For further information on the subject technology, please contact the listed organizations. Comments or questions about the Technology Transfusion Opportunities Program are welcomed and should be addressed to ALD/JTT, Wright-Patterson AFB, OH 45433-5000 or call AUTOVON 785-1606, Commercial (513) 255-1606.

NASA Tech Brief
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama

Holographic Reticle

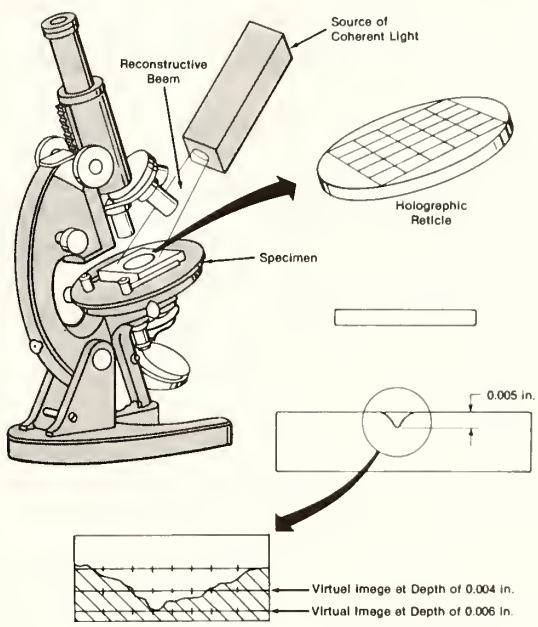
This device could be used for noncontacting, nondestructive inspection of surfaces.

A holographic reticle has been proposed for use in nondestructive evaluation of surface irregularities. Analogous to a common reticle used to measure the lengths and widths of surface features during visual inspection under a microscope, the holographic reticle would extend the inspection capability to include measurements of depth. Surfaces could be inspected without contamination, damage, or costly disassembly.

An inspector places a common reticle in the eyepiece of a microscope and views the surface to be inspected at a known magnification. A surface irregularity to be measured is aligned with a grid of calibrated lines on the reticle, and the inspector counts lines to determine the length and width of the irregularity.

To provide information on depth, a holographic reticle would be made to contain multiple calibrated images. The images would be projected from a common point to indicate focal planes at specific distances through the surface to be inspected. The hologram would produce virtual images in the object field of the microscope. These virtual images would serve as reference points in the object field. As each such image was brought into focus, a correlation would be made to the point at which the surface to be inspected came into focus. The surface to be inspected could then be said to lie at a depth between the depths of the holographic images above and below it.

An off-axis source of reconstructive light would be necessary for viewing of the hologram and the surface to be inspected under the microscope (see figure). The off-axis arrangement would allow for the projection of the hologram without reflection of the light into the microscope. (A hologram cannot be viewed with parallel light.) The holographic reticle would be calibrated by the use of known standards.



The **Holographic Reticle**, placed on the specimen, would produce virtual images of reticles of various depths into specimen.

Holographic reticles would provide valuable information that is now difficult to obtain. For example, such surface defects as corrosion and porosity, as well as the propagation of cracks, could be measured accurately. Roughness, wear, and plating thickness could also be measured. Holographic reticles could also be used to determine the quality of microcircuits.

This work was done by Edward A. Henn and Marc M. Scribner of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available.* *MFS-29597/TN*

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Medicine & Biology

0084 Defining the Link Between Diet and Cancer Risk

0085 Treatment for Africanized Bee Stings Possible

0086 Porous Elastomer for Use in Vascular Grafts, Artificial Organs, Permeable Drug Delivery Systems, and Other Uses

0087 Center For Fast Kinetics

0088 Stand-Aid Invalid Wheelchair Designed

0089 Emulsions Containing Perfluorocarbon Support Cell Cultures—An additive reduces mechanical damage to cells, promoting denser growth. (Licensing Opportunity)

0090 Indicator for Pseudomonas Bacteria—A characteristic protein is extracted and detected. (Licensing Opportunity)

Other Items of Interest

0034 Fireflies Light the Way to Improve Oil Yields

Defining the Link Between Diet and Cancer Risk

Risk assesment relies on educated guess, especially in the case of cancer where the disease may take a generation or more to express itself.

The more precise the data used, however, the more accurate the guess. In a few years, physicians and scientists may have a tool to better assess how diet influences a person's or a population's risk of developing some common cancers well before the disease arises. And the same tool may shed some light on whether or not the presence of pesticides or natural chemicals in groundwater increase our risk of cancer.

In an Agricultural Research Service laboratory at the Beltsville Human Nutrition Research Center in Maryland, biochemist Padmanabhan P. Nair and colleagues have adapted a French-developed test—which measures genetic damage in special bacteria—to indicate an increased potential for colon and possibly other types of cancer.

If the new technique continues to prove reliable in further studies, says Nair, "it should give physicians a more solid basis for advising individuals to modify their diet. And it should enable scientists to survey large populations and develop a national map showing relative risk rates in various geographic areas."

He led a group of researchers with ARS and the Johns Hopkins University in adapting the SOS Chromotest to study how dietary fat influences risk of colon cancer.

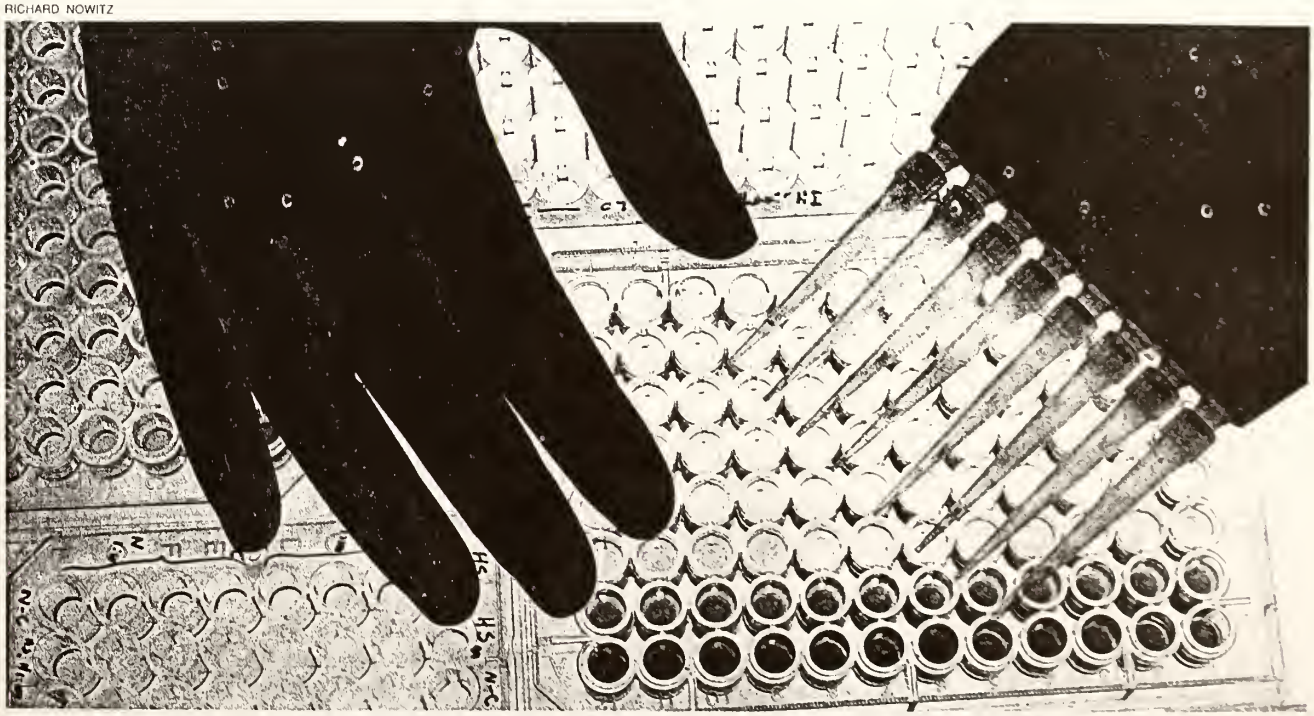
The test uses a genetically engineered *E. coli* bacterium to measure breakage, or mutations, of DNA. "This is a necessary step in the transition of cells from a normal to a malignant state," he says.

But how does one sort out the factors in a complex diet that could promote cancer? In the early 1980's, Nair directed a 5-year study of diet and cancer incidence comparing vegetarians, who ate less than 30 percent fat, with the general population living in Los Angeles.

The study showed that high-fat diets prompt intestinal microorganisms to produce more secondary bile acids, which are part of the fatty substance in stools that cause mutations. Also, the study found that the level of these acids is a good indicator of risk for colon cancer. Several other studies have corroborated these findings.

With this knowledge, he and assistants Samina Shami and Eduardo Sainz extract all the mutagens from human stools, apply the extract to the special bacteria, and measure the number of mutations. When 31 women in a controlled dietary study cut their fat intake in half—from 40 percent down to 20 percent of calories consumed—their stool extracts produced only half as many mutations, says Nair. Current studies of stool extracts from men are yielding

RICHARD NOWITZ



Genetically engineered *E. coli* bacteria activate an enzyme that produces a blue color in this SOS Chromotest. The color is proportional to the amount of DNA repair taking place. The test can be used to assess how diet influences a person's risk of developing some forms of cancer. (K-3543-3)

similar results.

"We have suggested a biochemical basis for the link between high-fat diets and the chance of developing colon cancer," he says. "While mutations don't automatically lead to cancer, we believe they clearly increase the risk. This has been established in animals but is still under study with humans."

He predicts that testing stool sample extracts may also prove to be a good indicator of risk of breast and other cancers. That's because fatty mutagens in the colon can be reabsorbed and deposited in the breast and other organs having fatty tissue. And most cancers occur in cells similar to those that line the colon.

The rationale is that mutations, or breakage, of DNA can lead to malignancy. Before a normal cell can become a cancer cell, inactive cancer-promoting genes known as protooncogenes have to be cut and spliced into a new place on the DNA to become active oncogenes, he explains. "That's like rearranging the garbled letters of an anagram to spell a word that makes sense."

The more breaks in the DNA, the greater the chance the dormant protooncogenes will be rearranged into active oncogenes as the huge molecules are spliced back together.

In the SOS Chromotest, the genetically engineered *E. coli* bacteria signal DNA repair by activating an enzyme that generates a blue color. The strength of the color is proportional to the amount of enzyme produced, so the tester can measure breakage by using a color standard produced with a known mutagen.

Similar tests, such as the Ames test, distinguish chemicals that cause mutations (mutagens) from those that don't. But they don't indicate the amount of breakage, says Nair.

He hopes to train health-care faculty from universities and medical schools in how to achieve accurate results with the screening test. They, in turn, can teach their colleagues and students.

"We should be able to project how a change in diet will change risk," he says. "We've done it in the lab, but we need to test it nationally."

Others involved in the research include Joseph T. Judd and George P. Albaugh of the Agricultural Research Service, and Lois B. Jerabek, Vasantha Iyengar, Samina Shami, and Althaf Lohani of the Johns Hopkins University.

Diet is only one aspect of risk, he says. Other aspects are heredity, factors that activate foreign cancer-promoting genes present in human cells, and exposure to cigarette smoke and other environmental carcinogens.

Within the next year, Nair hopes to add other tests for assessing the total risk profile for cancer. "The adapted chromotest is only one quarter of the total picture," he says.

The SOS Chromotest was developed at the Pasteur Institute in France primarily to screen industrial compounds for mutagenicity, says Nair. So he introduced the test to environmental chemist Jack R. Plimmer at the Beltsville center, who was looking for a way to assess groundwater for cancer risk.

Nair's group is measuring mutagenicity of groundwater samples collected from selected locations, while Plimmer's group is analyzing the samples for total carbon—the backbone of all organic compounds.

Plimmer's lab will also analyze for pesticides and other carbon-containing pollutants. "This test correlates very positively with mutagenicity," he says.

With $45.4 million in new appropriations to protect groundwater, USDA recently launched a 5-year plan to reduce the presence of pesticides and fertilizer. Doral Kemper, who oversees ARS' soil management research, says if groundwater were tested nationwide, then a national map of mutagenicity could be developed.

He says such testing could gauge the risk posed by pesticides against that posed by natural compounds, such as those released by decaying plants. According to ARS water analysts, Kemper says, pesticides account for less than 1 percent of all organic compounds in groundwater, lakes and streams. And Bruce Ames of the University of California, Berkeley, developer of the Ames test, concludes that natural compounds in water are about as likely to cause mutations as manmade compounds.

Kemper notes that filtration plants remove many of these organic compounds from city water.

Padmanabhan P. Nair, is at the USDA-ARS Lipid Nutrition Laboratory, Beltsville Human Nutrition Research Center, Beltsville, MD 20705 (301) 344-2145. ◆

Treatment for Africanized Bee Stings Possible

Developing an antivenom treatment for Africanized bee stings should be feasible, says ARS' Justin O. Schmidt, because the venom is quite similar to that of domestic honey bees. Entomologist Schmidt and coworkers at the Carl Hayden Bee Research Center in Tucson, Arizona, compared proteins in the venom of more than 1,000 bees of each race and found only minor differences. In fact, antibodies against honey bee venom found in a blood sample from a commercial beekeeper proved useful in counteracting Africanized bee venom.

Despite their fearsome reputation - Africanized bees may have killed as many as 600 people worldwide - individual bees contain less venom than European bees. And this venom is not more toxic either, says Schmidt, who tested it with laboratory mice.

"However, the danger to humans posed by Africanized bees is still very real. These bees are extremely defensive, and unlike European bees who typically attack only a few at a time, Africanized bees can go on an attack frenzy with hundreds storming a victim at the same time," he says.

"I'd compare an attack by 500 bees to roughly the equivalent of a rattlesnake bite. Most persons who are massively envenomed by hundreds of Africanized bee stings would become very ill even with the present treatments designed for European stings," says Schmidt, who cooperated in the studies with University of Arizona allergist Michael J. Schumacher, M.D.

FOR ADDITIONAL INFORMATION: Justin O. Schmidt is at the USDA-ARS Carl Hayden Bee Research Center, 2000 East Allen Road, Tucson, AZ 85719; (602)670-6380.

Department of Defense Fact Sheet

Strategic Defense Initiative Organization

Porous Elastomer for Use in Vascular Grafts, Artificial Organs, Permeable Drug Delivery Systems, and Other Uses

A process originally developed for a Strategic Defense Initiative fuel application under a Department of Energy contract is being used to form small pores in biomedical-grade polyurethane elastomers. The process, developed by Dr. Peter Rand and others at Sandia National Laboratories in Albuquerque, New Mexico, can control pore size, density and cell organization. Researchers believe that the process offers a solution to clotting or thrombosis (the leading cause of failure of vascular grafts and other implants), and that, for this reason, elastomers made with this process could be used in vascular transplants, artificial organs, artificial skin, and permeable drug delivery systems.

When elastomer treated with this process is formed into tubes and used as vessels or veins, pores can be distributed throughout the tubing much like pores are distributed in a sponge. Cells of various types are then implanted into these pores, in a manner imitating cellular function in vessels and veins.

Dr. Paul Mann, Chief of Research at the Center for Non-Invasive Diagnosis at the University of New Mexico, is using tubing with pore size ranging from 40.0 microns near the inner perimeter to 100.0 microns nears the outer perimeter. In Dr. Mann's research, fibroblast, cells that give rise to connective tissue, is placed on the outside ring of the tubing. Fibroblast seals the tubing against invasion by body tissue (current tubing becomes clogged by tissue ingrowth). Biological cellular material is placed on the inside ring to imitate smooth muscles. Finally, endothelial cells are placed on the surface of the tubing which contacts the blood (the inner or lumenal surface). These endothelial cells modulate the clotting of blood; thus their placement on the luminal surface of the artificial vein allows them to be directly positioned to modulate clotting.

Current biomedical tubing small enough to be used for veins and vessels is non-porous, and cannot be used to host these endothelial cells. Thus the tendency to clot cannot be controlled.

Use of biomedical grade elastomer treated with this process could greatly reduce the risk of rejection in transplants. Ability to modulate clotting could lead to tubing being used in neural surgery and vascular replacement surgery, including cardiac bypass. Other possible applications of the foam include artificial skin, artificial organs, and use in permeable drug delivery systems.

FOR ADDITIONAL INFORMATION: For Further Information on Sandia Microporous Elastomers, Contact: Dr. Peter Rand, Sandia National Laboratory, Division 1813, Albuquerque, NM 87185; (505) 845-8695. For Program Information Contact: Technology Applications Office, Strategic Defense Initiative Organization, OSD/SDIO/TNO, Washington, DC 20301-7100; (202) 653-1442.

NIH
Research & Technology
Federal laboratory resource
U.S. Department of Health and Human Services Public Health Service National Institutes of Health

Center For Fast Kinetics

The Center for Fast Kinetics Research (CFKR) at the University of Texas at Austin provides researchers with an assortment of lasers and electron accelerators for studying extremely short-lived but important intermediate reactants that occur in chemical and biochemical systems. The biochemistry of vision and photosynthesis, the biological effects of ionizing radiation, the interaction of carcinogenic environmental pollutants with DNA, and the mechanism of repair of damaged DNA are among the topics that have been studied at the center, according to Dr. Marye Anne Fox, Rowland Pettit Centennial Professor of Chemistry and director of the CFKR.

Since it opened in 1975, researchers from such diverse disciplines as organic, inorganic, and physical chemistry, photochemistry, photophysics, dermatology, cancer research, and ophthalmology have used the CFKR, Dr. Fox notes. The facility, which is funded by the Biomedical Research Technology Program of the National Center for Research Resources and by the University of Texas, allows researchers to initiate and study electron transfer reactions by two methods. In one of them, called pulse radiolysis, the reactants are exposed to a beam of accelerated electrons, which initiates the reaction. In the other method, called laser flash photolysis, a chemical reaction is initiated by exposing the reactants to the light of a laser beam for extremely short periods of time.

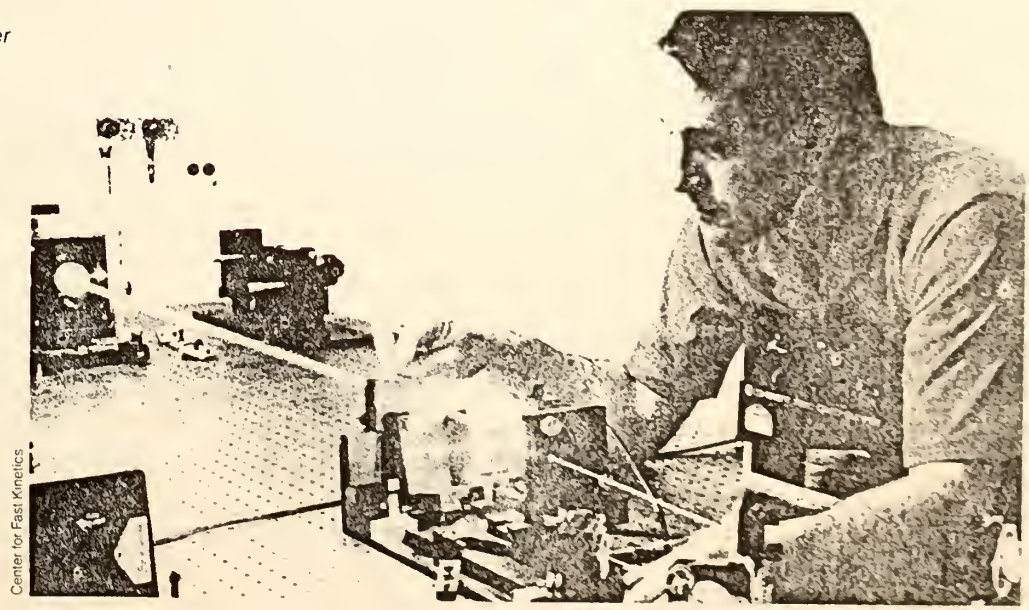
"The addition of the laser flash photolysis systems to the original pulse radiolysis systems has allowed us not only to enhance the time resolution of the reactions we can study but also to increase the types of reactions we can study," Dr. Fox says.

For example, the laser systems can be used to exploit the ability of complex macromolecules to absorb energy from an intense monochromatic (single-wavelength) light source. Such photoreactive molecules may store the light energy, or photons, for periods much less than 1 nanosecond (one-billionth of a second) as vibrational energy in an electronically "excited state." When the electrons in the excited molecules return to their normal, or ground, state, the vibrational energy is re-emitted as light—a phenomenon known as fluorescence—or heat or both.

"By looking at the absorption or emission energy of a molecule at a number of wavelengths of light as a function of time—a technique known as time-resolved spectroscopy—we can determine the absorption, excited state, and emission lifetimes of a molecule," Dr. Fox explains. Such information can tell investigators a great deal about the structure of a molecule and how that structure is affected by energy transfer, she adds.

The laser systems can also be used to create molecules that are electronically unstable, or have an "unpaired" electron, Dr. Fox says. Molecules with unpaired electrons are known as free radicals; they tend to scavenge electrons from other molecules and are therefore often harmful to living organisms, she explains.

The CFKR has six independent laser and pulse radiolysis workstations. Two pulsed laser photolysis stations can be used to create and detect excited states and free radicals with life-



Center for Fast Kinetics

Timothy J. Callan at the Center for Fast Kinetics adjusts the laser beam in a single-photon counting station. With this method fluorescent molecules can be analyzed within extremely short time spans.

times as short as 1 nanosecond. An additional pulsed laser excitation station can detect excited molecules with absorbing and fluorescing lifetimes of only 30 picoseconds (thirty-trillionths of a second). A time-correlated single-photon counting station is available for determining fluorescent lifetimes in the 100-picosecond range. Two fully independent electron pulse radiolysis stations can detect transient species in a number of energy transfer reactions with nanosecond lifetimes using a variety of detectors. All six workstations have instrumentation for ultraviolet and visible absorption and emission spectroscopy. An extensive array of computer software has been developed by the CFKR staff to aid researchers in experimental analysis, and the facility also has its own machine and electronics shop.

"In addition to the independent laser and the pulse radiolysis systems, we also have an experimental station that can do simultaneous excitation," Dr. Fox says. "One can take a sample and excite it with pulse radiolysis and then probe the intermediates that are generated by the pulse radiolysis with a laser, or vice versa."

Researchers have used the CFKR laser flash photolysis and pulse radiolysis systems to study the photophysical properties of retinal, the primary pigment involved in vision. They have also studied the binding sites for metal ions on DNA—in connection with a determination of the distribution of carcinogen-induced chromosomal mutations. The system has been used to create a variety of free radicals and to study their interactions with different chemical and biological environments.

Recently, researchers used lasers to study a dye called Merocyanine 540, which selectively binds to and kills certain types of cancer cells when exposed to a particular wavelength of light. The investigators showed that laser stimulation induced a brief change in the three-dimensional structure of the Merocyanine 540 molecule when it was bound to a cell membrane. The structure of free dye molecules did not change. The researchers concluded that Merocyanine 540 destroys cancer cells either by re-emitting the laser energy as heat and thus "cooking" the cell membrane or by rupturing the cell membrane when the dye molecules change shape.

Investigators at the CFKR have also recently constructed several models of cells that are simpler than living cells but are based on the same physical chemical properties. By determining how free radicals affect different microenvironments within a cell, the researchers are attempting to reconstruct the sequence of events that take place between the initial delivery of ionizing radiation and its final biological effects.

Although the facility is currently operating near capacity, Dr. Fox says the CFKR Advisory Committee uses a priority system that allows access within a relatively short period of time. NIH-funded research is given priority over non-NIH-funded research; health-related (biomedical) research, biological research, and outside projects in general are given priority over non-health-related, nonbiological, and in-house projects. In addition, researchers with established research projects are given priority over investigators proposing experiments that have not been tried before.

Although many researchers collaborate with CFKR staff members, such collaboration is completely voluntary and priority for use of the facility is not based on collaboration, Dr Fox emphasizes. In 1989 a total of 110 researchers working on 60 independent projects used the facility.

Four Ph.D. scientists on the CFKR staff aid users of the facility. For researchers familiar with the CFKR instrumentation, the degree of interaction with the staff may be minimal; for novice users staff personnel run all of the initial experiments until the user gains enough experience to operate the equipment unassisted, Dr. Fox says.

For further information contact:
Dr. Stephen J. Atherton or
Dr. Anthony Harriman
Center for Fast Kinetics Research
University of Texas at Austin
Austin, Texas 78712 Telephone:
(512) 471-7583
FAX: (512) 471-6095
Telex: 9108741305 UT INTERNAT AUS

For Additional Information:

To locate information or professional contacts on this effort, contact:

Research Resources Information Center
1601 Research Boulevard
Rockville, MD 20850
(301) 251-4970

Refer to Volume XIV, No. 8/TN

Stand-Aid Invalid Wheelchair Designed

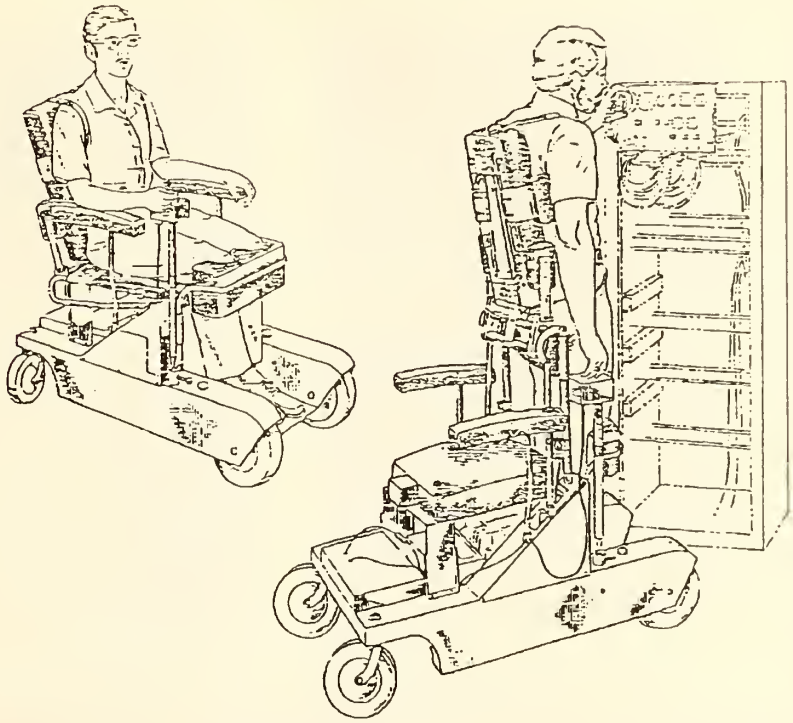


Figure 3. Stand-aid invalid wheelchair

The Naval Ocean Systems Center (NOSC), San Diego, California, under the sponsorship of the Veterans Administration, has designed a wheelchair (see Figure 3) to enable an invalid to stand, sit, or choose at will, any intermediate position to perform useful work. This will give the invalid the freedom to move about in any of the chosen positions without the assistance of others.

The mechanism that lifts and lowers the invalid to and from a standing position is done in a natural and comfortable manner and without the dislocation of the individual's clothing. There is a minimum of physical encumbrances permitting the invalid to function near normally in the average living or working spaces. The wheelchair will help to fulfill the psychological and physiological needs of handicapped persons.

For Additional Information:

Backup material on this effort is available from:

Navy Domestic Technology Fact Sheet Reader Reply Service
Code E211
Naval Surface Weapons Center
Dahlgren, VA 22448-5000
(703) 663-8921

Refer to 150403/TN

NASA Tech Brief
National Aeronautics and Space Administration
Lyndon B. Johnson Space Center, Houston, Texas

Licensing Opportunity

Emulsions Containing Perfluorocarbon Support Cell Cultures

An additive reduces mechanical damage to cells, promoting denser growth.

The addition of an emulsion containing a perfluorocarbon liquid to an aqueous cell-culture medium increases the capacity of the medium to support mammalian cells. The perfluorocarbon — FC-40 Fluorinert (or equivalent) — increases the average density of the medium so that it is approximately equal to that of the cells. The cells therefore stay suspended in the medium without mechanical stirring, which damages them. A volume fraction of 11.49 percent of the perfluorocarbon added to the aqueous medium increases the density enough to prevent the cells from settling.

In addition, the emulsion increases the viscosity of the medium so that oxygen can be bubbled through it and nutrients can be stirred in with less damage to the delicate cells. It has been hypothesized that droplets of the emulsion become attached to the gas/liquid interfaces of bubbles, preventing the cells from becoming entrained in the circulation of liquid at the interfaces.

In experiments with hybridoma cells, bioreactors with the perfluorocarbon emulsion supported cells at densities as high as $2.5 \times 10^6\ mL^{-1}$. Without the emulsion, the densities of cells in the same bioreactors remained below $1 \times 10^5\ mL^{-1}$ because of the damage caused by the flow of gas needed to keep the cells in suspension in the medium.

Moreover, the emulsion enhances the transfer of cells: about 2.5 times as much oxygen gets to the cells in the presence of the emulsion as in its absence at the same rate of flow. The emulsion also enables cells to withstand higher rates of flow: in one case, hybridoma cells in columns without the emulsion were severely damaged, but were not damaged appreciably even at a rate 27 percent higher when the emulsion was used.

This work was done by Lu-Kwang Ju, Jaw Fang Lee, and William B. Armiger of **Johnson Space Center.**

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

President, Bio-Chem Technology, Inc.
66 Grant Valley Parkway
Malvern, PA 19355

Refer to MSC-21480/TN.

Lyndon B. Johnson Space Center
Technology Utilization Officer: Dean C. Glenn
Mail Code IC-4
Houston, TX 77058
(713) 483-3809
Patent Counsel: Edward K. Fein
Mail Code AL3
Houston, TX 77058
(713) 483-4871

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Licensing Opportunity

Indicator for Pseudomonas Bacteria

A characteristic protein is extracted and detected.

A natural protein marker has been found in *Pseudomonas* bacteria. It may be possible to develop a simple, fast, and accurate test for the marker that can be carried out in a doctor's office. Until now, it has been necessary to use tedious, costly, and time-consuming microbiological techniques to identify the bacteria. The marker is azurin, a protein that contains copper. It can readily be extracted, purified, and used to prepare antibodies.

In a laboratory demonstration of the effectiveness of the marker, a centrifuged extract of *Pseudomonas* culture was separated into components by gel electrophoresis. The separated components were transferred from the gel to a nitrocellulose membrane with a semidry electroblotter.

The free binding sites on the membrane were blocked with bovine serum albumin. The membrane was incubated overnight in a primary antibody solution (antiazurin) and for 2 hours in a secondary antibody solution. An enzymatic staining solution was applied to the wet membrane. The presence of *Pseudomonas* was indicated by dark stains on the membrane (see figure).

This work was done by Ruth Margalit of Caltech for **NASA's Jet Propulsion Laboratory**.

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office-JPL. Refer to NPO-17653/TN.

Jet Propulsion Lab.
NASA Resident Office
Technology Utilization Officer: Gordon S. Chapman
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4800 Oak Grove Drive
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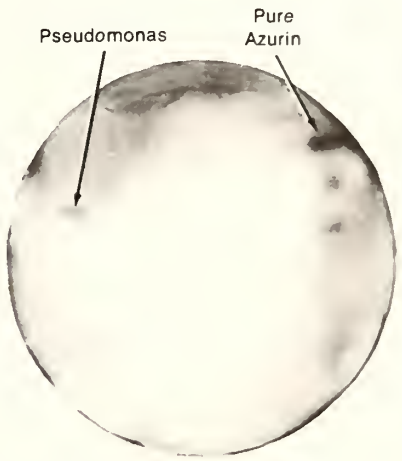
(818) 354-2734
Technology Utilization Mgr. for JPL: Norman L. Chalfin
Mail Stop 156-211
4800 Oak Grove Drive
Pasadena, CA 91109
(818) 354-2240



Pseudomonas Bacteria Appear as a stain on a nitrocellulose membrane. Pure azurin also shows up as a stain.

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

Natural Resources Technology & Engineering

0091 X-Ray Fluorescence Spectrometry Ore Available

0092 Preliminary Analysis of Data From AVIRIS—Radiometric calibration in flight and determination of reflectance of the ground are discussed.

Software

0093 Computer Program for Seismic Signal Analysis

Testing & Instrumentation

0094 Meteorological Data Systems to Track Balloon Borne Meteorological Radiosonde

NIST Technology Update

National Institute of Standards & Technology

U.S. Department of Commerce, Gaithersburg, MD 20899

X-Ray Fluorescence Spectrometry Ore Available

A new fused ore X-ray fluorescence spectrometry standard has been developed by NIST for laboratories that analyze the constituent elements in rocks, ores, and clay. Standard reference material (SRM) 1834 is a silica base glass disk, 3 centimeters in diameter by 0.3 centimeters thick, for calibrating instruments. The synthetic glass material has an elemental composition similar to SRM 97a, Flint Clay, with the amount lost on ignition replaced by oxides of lithium and boron. SRM 1834 also can be used in quality-control applications and to monitor instrument stability. The new SRM has certified weight percent values for the following constituent elements: aluminum, barium, calcium, iron, magnesium, phosphorus, potassium, silicon, strontium, and titanium.

FOR ADDITIONAL INFORMATION: SRM 1834, Fused Simulated Ore for X-ray Fluorescence Spectrometry, is available for $298 from the Standard Reference Materials Program, Rm. 215 Bldg. 202, NIST, Gaithersburg, Md. 20899; 301/975-6776.

NASA Tech Brief
National Aeronautics and
Space Administration

Preliminary Analysis of Data From AVIRIS

Radiometric calibration in flight and determination of reflectance of the ground are discussed.

A report presents a preliminary analysis of the performance of the Airborne Visible/Infrared Imaging Spectrometer (AVIRIS), a scanning instrument that produces images at wavelengths from 400 to 2,450 nm. The AVIRIS includes four spectrometers connected by optical fibers to a common set of foreoptics. The analysis focuses upon the calibration of the instrument and determination of the reflectance of the surface of the Earth from its measurements.

The purposes of this study were (1) to develop in-flight spectral and radiometric calibrations for the instrument and (2) to compare various empirical and theoretical methods of compensating for the effect of the atmosphere in recovering the spectral reflectance of the surface from radiances measured by the instrument at altitude. For these purposes, the following data (in addition to the AVIRIS data) were obtained:

- Optical depth of the atmosphere from measurements with solar radiometers;
- The ratio of diffuse to direct incident light at the surface of the Earth from measurements with a hand-held radiometer;
- The total precipitable water from measurements with a ratioing spectral hygrometer; and
- Spectral reflectances of a bright playa surface, a dark runway, and a concrete tarmac from measurements with a portable spectrometer ordinarily used to estimate average reflectances of calibration targets.

To meet the calibration objective, the radiance calculated from AVIRIS data taken while viewing the bright playa target was determined according to the responsivities of the AVIRIS measured in a laboratory, then compared with the radiance of that target as measured on the ground and corrected by the LOWTRAN 6 mathematical model of the transmittance and reflectance of the atmosphere. The model includes a catalog of strengths and wavelengths of atmospheric absorption bands, which were used as references to check the wavelength calibration and spectral resolution of the AVIRIS.

To meet the spectral-reflectance objective, the reflectances of the playa and runway were taken together with the spectral responses of the AVIRIS to develop linear empirical equations, which were then used to predict the reflectance of the tarmac. Next, using the runway as a spectrally flat reference, an equivalent reflectance of the tarmac was computed from the ratios of the radiances of the tarmac to those of the runway as measured by the AVIRIS. Finally, the radiances derived from the AVIRIS data, corrected by the LOWTRAN 6 model, were used to invert the model and recover the reflectance of the surface.

The comparisons between in-flight radiances, predicted from the laboratory calibration, and radiances generated by the atmospheric model for flight conditions showed apparent agreement to within a few percent at wavelengths from 1,800 to 2,450 nm. Between 600 and 1,800 nm, the response of the AVIRIS was found to be systematically low by as much as 70 percent, and between 400 and 600 nm, it was found to be higher than expected. These observations are tentatively traced to thermal distortions of the instrument, and to detachment, during flight, of optical fibers to two of the spectrometers. Of the three tested methods for calculating the reflectance of the surface, the best one proved to be the first (empirical) one.

This work was done by James E. Conel, Gregg A. Vane, Robert O. Green, Ronald E. Alley, Veronique Carrere, Carol J. Bruegge, of Caltech and Andy Gabell of CSIRO, Perth, Australia for **NASA's Jet Propulsion Laboratory**. *"Airborne Visible/ Infrared Imaging Spectrometer (AVIRIS): In-flight Radiometric Calibration and the Determination of Surface Reflectance."*
NPO-17622/TN

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

Computer Program for Seismic Signal Analysis

Approach

The Bureau has developed BOMSPS (Bureau of Mines Signal Processing Software) to provide the mining industry a signal processing program for the enhancement of geophysical data. BOMSPS is a comprehensive software package that provides for improved signal quality to assist in the interpretation of seismic data collected in mining operations. The software can analyze various time- and frequency-domain attributes and possesses filtering capabilities. Postdigital enhancement by BOMSPS to band-limit or reject selected information provides greater resolution for necessary interpretations. The software is an inexpensive tool for the geophysicist, engineer, and/or researcher performing seismic surveys in mining and environmental operations.

How It Works

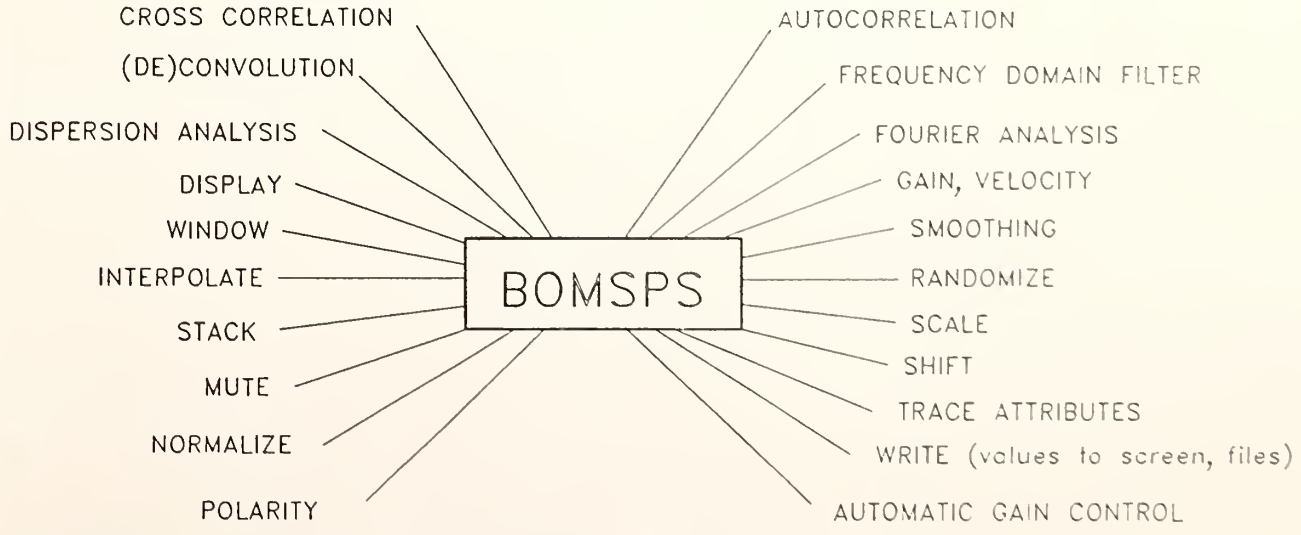
BOMSPS consists of nonproprietary code for signal processing and interpretation of geophysical data. It is written for IBM or compatible PC's in FORTRAN and C languages. The program consists of several modules that can be used to filter, enhance, and interpret seismic and electromagnetic signals. Operations such as automatic gain control, muting, normalization, polarity conversion, randomization, scaling, shifting, stacking, smoothing, and windowing account for the basic time-domain operations.

Objective

Develop personal computer (PC) based software for analyzing and/or filtering time- and frequency-domain attributes of seismic and electromagnetic signals from geophysical surveys for the enhanced interpretation of rock masses and subsurface geologic structure.

The Problem

Both mining and petroleum geophysicists utilize seismic signals to characterize rock masses for delineating subsurface stratigraphy and structural conditions. However, a vast amount of information available in seismic project evaluation data often is unavailable for interpretation unless these data are enhanced. New processing technology increases the quality of these signals for analysis and interpretation. Comprehensive signal processing software is mostly written for petroleum exploration companies. Commercially available signal processing programs are often limited to a single application or are restricted for use with specific hardware, e.g., a digital oscilloscope or a mainframe computer. The programs may use computer codes that are proprietary, restrict user modification to expand capabilities, or may be hard to interface. They may have insufficient documentation for easy use and be support dependent.



Modules of the BOMSPS program.

Higher order time-domain enhancement capabilities involve convolution, deconvolution, autocorrelation, and cross correlation. Frequency-domain attributes such as the real and imaginary transforms, relative amplitude, power, phase, dynamic amplitude, and dynamic power spectra can be determined. Frequency-domain filter capabilities permit the investigator to employ a half-sine or cosine window, band-pass, notch, high pass, and/or low pass filters, while interactively defining the rolloff of either a linear or cosine taper. Calculation of related trace attributes such as quadrature (Hilbert transform), instantaneous amplitude, and instantaneous phase are also available.

The program is documented in detail in Bureau Information Circular (IC) 9242. The IC details those signal processing conceps and expressions incorporated into the BOMSPS code and provides a user's document for implementation of the code. The Fourier transformation and its properties are reviewed to illustrate applicability in developing those mathematical expressions used as digital operators. The advantages and limitations of basic and higher order time- and frequency-domain operations are discussed. The examples and easy-to-follow menus outlined in the tutorial facilitate the implementation of BOMSPS on a routine basis.

For More Information

For a free single copy of IC 9242, write to the Bureau's Publication Distribution Section, Building 149, P.O. Box 18070, Cochrans Mill Road, Pittsburgh, PA 15236-0070.

Source and executable codes in FORTRAN (signal processing) and C (graphics) are available from the principal investigators listed below. Requests for the software package should reference this article and include a high-density IBM PC or compatible 5-1/4- or 3-1/2-inch diskette. Additional information may by obtained by contacting:

M. J. Friedel or K. S. Roessler
Twin Cities Research Center
U.S. Bureau of Mines
5629 Minnehaha Avenue South
Minneapolis, MN 55417-3099
(612-725-4500)

U.S. Army Fact Sheet

Meteorological Data Systems to Track Balloon Borne Meteorological Radiosonde

The MDS, AN/TMQ-31 is a mobile, versatile, automated meteorological data acquisition and processing system with nonradiating ground based components. "The function of the system is to automatically track a balloon borne meteorological radiosonde as it ascends the atmosphere; receive its telemetered signals of temperature, relative humidity, pressure and NAVAID data; measure elevation and azimuth angles to the radiosondes, automatically convert and process the data; automatically compute meteorological messages for transmission to the user via wire radio.

Production units are presently being fielded.

The MDS "sounds" the atmosphere and measures temperature, humidity, pressure (winds aloft) at high altitudes. State governments may be interested in tornado and hurricane prediction, volcanic plume dispersion, air sampling to determine path of pollutants, acid rain fallout, synoptic measurements and the like.

FOR ADDITIONAL INFORMATION: 1. U.S. Army Field Artillery School, Fort Sill, Oklahoma 73503; Telephone: (405)351-3652, POC: Mr. Charles Taylor. 2. U.S. Army CECOM Center for Electronic Warfare/Reconnaissance Surveillance and Target Acquisition, Fort Monmouth, New Jersey 07703-5000; Telephone: (201)544-3183, POC: Mr. Frank Wilson.

Physical Sciences

0095 Method for the Recovery of Silver from Silver Zeolite (Licensing Opportunity)

0096 Behavior of Evaporating Liquid Drops in Clusters—Progress in understanding combustion of sprayed fuels and related phenomena is discussed.

0097 Concurrent Algorithm for Particle-in-Cell Simulations—Separate decompositions are used for the particle-motion and field calculations.

Testing & Instrumentation

0098 Analyzing Environmental Pollutants (Licensing Opportunity)

0099 Differentiating Mirror-Image Molecules (Licensing Opportunity)

0100 High-Temperature Quantitative Dilution Device for Oxides of Nitrogen Measurements via Chemiluminescent Monitors (Licensing Opportunity)

0101 Compensating for Doppler Shift in Laser Instrumentation—The frequency of a tunable diode laser is adjusted to oppose the shift. (Licensing Opportunity)

0102 Concentrating Gaseous Contaminants for Monitoring—Amounts of outgassed substances can be analyzed as functions of time and temperature.

0103 High-Pressure Promoted-Combustion Chamber—An improved version of an existing chamber would burn specimens in oxygen. (Licensing Opportunity)

Other Items of Interest

0057 Evaluation of an Anion Exchange Resin for Sampling Ambient Level Phenolic Compounds

0058 Laboratory Method to Estimate Hydrogen Chloride Emission Potential Before Incineration of a Waste

0059 Materials Can Help Evaluate Industrial Atmosphere

0087 Center For Fast Kinetics

0091 X-Ray Fluorescence Spectrometry Ore Available

0094 Meteorological Data Systems to Track Balloon Borne Meteorological Radiosonde

Department of Energy

Technology Application

Idaho National Engineering Laboratory

Method for the Recovery of Silver from Silver Zeolite

The removal of airborne radioactive iodines from the atmosphere to prevent surface contamination and possible human ingestion is an important factor in nuclear safety. These radioactive iodines include inorganic species such as elemental iodine, and organic species such as methyl iodine. They may be present in reactor containment vessels from normal reactor operations and in fuel element cladding failure, and are present in dissolver off-gasses from nuclear fuel reprocessing plants. These radioactive iodines are formed in the nuclear fuel by the fissioning of the fuel material. High-purity silver is recovered from silver-exchanged zeolite used to capture radioactive iodine from nuclear reactor and nuclear fuel reprocessing environments. The silver-exchanged zeolite is heated with slag formers to melt and fluidize the zeolite and release the silver, removing the radioactivity with the slag. The silver, containing metallic impurities, is remelted and treated with oxygen and a flux to remove the metal impurities. About 98% of the silver in the silver-exchanged zeolite, having a purity of 99% or better, is recoverable by the method.

Applications of this technology are nuclear related.

Laboratory Name: Idaho National Engineering Laboratory.

Reference No.: DOE-INEL-057.

Patent Status: U.S. Patent No. 4,564,391. Available for licensing.

FOR ADDITIONAL INFORMATION: Streier, G.G., Manager, ORTA, EG&G Idaho, Inc., P.O. Box 1625, Idaho Falls, ID 83415-3561; Telephone: FTS: 583-6042; Commercial: (208)526-6042.

NASA Tech Brief
National Aeronautics and
Space Administration

Behavior of Evaporating Liquid Drops in Clusters

Progress in understanding combustion of sprayed fuels and related phenomena is discussed.

A report presents a critical analysis of methods, developed during recent years, for calculating the behavior of evaporating liquid drops in dense and dilute clusters. These methods are essential to understanding the variety of physical and chemical phenomena that occur in the combustion of sprayed fuels and in the sprays used in agriculture, the food industry, and painting. The report includes an extensive review of contributions made by the author and others and presents insights on important aspects of two-phase flow.

The first section of the report is an introduction. It discusses the motivations for studies of this kind, then presents a summary of previous studies in the context of both the previously evolving and current partial understanding of the phenomena. It includes a topic that is essential to understanding the remainder of the report: the characterization of sprays by the simultaneous use of widely different length scales. These include the scale of the enclosure, if any, where the liquid is sprayed; the many scales associated with the turbulence; the scale of interactions among drops; the average distance between drops; and the sizes of the drops. The wide disparities (typically, many orders of magnitude) among these scales makes an accurate mathematical description at all scales impractical. One way to circumvent this difficulty is to perform detailed calculations on behavior of the macroscale (which is the scale where the phenomena of interest to engineers occur) while computing the behavior on the much smaller microscale in an approximate and global manner.

The coupling between the two scales must be achieved through the boundary conditions at the microscale level. A microscale formulation is also sometimes called a subscale or subgrid model because the phenomena that are involved occur at a scale much smaller than that of the grid size used to solve the macroscale problem computationally. Inherent to this two-level description is the understanding that the subscale models are more approximate than the macroscale models are and lack the detail that the latter ones are required to have in order to be useful.

The second section of the report presents a survey of mathematical models that pertain to interactions among a few drops. While these models are of interest in helping to understand departures from models of single, isolated drops, they cannot realistically represent the behavior of large numbers of drops, and, therefore, are not candidate subgrid models. Moreover, these models are not economically suitable as subgrid models because they require excessively large computational resources.

The third section discusses the approach taken by the author and her coworkers in the mathematical modeling of interactions among many drops. The topics in this section include (1) constant-volume (variable-pressure) cluster models of evaporation of drops and (2) constant-pressure (variable-volume) cluster models of evaporation of drops, ignition and combustion of drops, and evaporation and dispersion of electrically charged drops. It is shown that despite some shortcomings, the approach described may be useful in the development of subgrid models.

The fourth section draws conclusions from the various models and from the results of specific computations performed with them. In particular, it describes the major differences between the evaporation, ignition, and combustion behaviors of dense and dilute clusters of drops. It suggests ways in which understanding of the phenomena in sprays can be improved by future research.

This work was done by Josette Bellan of Caltech for **NASA's Jet Propulsion Laboratory**. *"Liquid Drop Behavior in Dense and Dilute Clusters."*
NPO-17843/TN

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
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NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

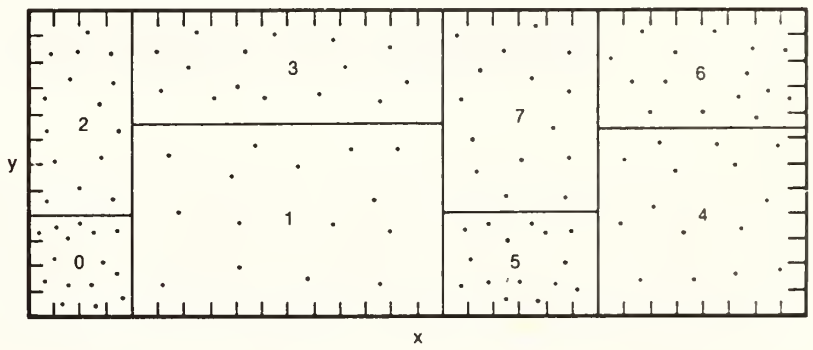
Concurrent Algorithm for Particle-in-Cell Simulations

Separate decompositions are used for the particle-motion and field calculations.

The General Concurrent Particle-in-Cell (GCPIC) algorithm is used to implement the motions of individual plasma particles (ions and electrons) under the influence of particle-in-cell (PIC) computer codes on concurrent processors. PIC codes simulate the motions of individual plasma particles (ions and electrons) under the influence of the electromagnetic fields generated by the particles themselves. Simulations are performed to study a variety of nonlinear problems in plasma physics, including magnetic and inertial fusion, plasmas in outer space, the propagation of electron and ion beams, free-electron lasers, and particle accelerators. Because the computation time in the PIC method is roughly proportional to the number of particles, it is desirable to use the GCPIC algorithm to take advantage of the speedup offered by concurrent processing for realistic simulations that require thousands to millions of particles.

To keep the amount of computation manageable, a PIC code provides for a discrete spatial grid to solve Maxwell's equations for the electromagnetic fields generated or modified by the plasma particles. At each time step, the charge and current densities generated by the plasma are calculated at the grid points by interpolation of the present positions and velocities of the particles. The electromagnetic fields at the next time step are found by solving the field equation on the discrete grid. Finite-difference or Fourier-transform methods can be used; the form of the equations used and the method for solving them depend strongly on the problem. To update the positions and velocities of the particles at the next time step, the new fields and forces at the locations of the individual particles are found by interpolating from the electromagnetic fields at the grid points.

The GCPIC algorithm is designed to make the most computationally intensive portion of a PIC code — updating the particles and the resulting charge and current densities — run efficiently on concurrent processors. The time to make these updates, termed the particle "push time," is defined to include the time to update the particle positions and velocities (including the interpolation to find the forces at the particle positions) and to "deposit" (interpolate) the contributions of the particles to the charge and current densities onto the grid. Generally, this push time is about 90 percent of the total computation time.



In a **Two-Dimensional Problem With Equally-Spaced Grid Points,** an equal number (15) of particles is assigned to each of 8 subdomains of different sizes. The computations for the particles in each subdomain are assigned to one of eight concurrent (parallel) processors.

The principal feature of the GCPIC algorithm is two distinct spatial decompositions that mirror the two stages of a PIC code: a primary decomposition is used to divide the particles and particle computations efficiently among the concurrent processors, and a secondary decomposition is used to divide the electromagnetic-field computation among the processors. For the primary decomposition, the physical domain of the simulation is divided into N_p subdomains such that these subdomains have roughly equal numbers of particles. This balances the computation and memory loads among the processors and minimizes interprocessor communication time.

For problems with nonuniform particle densities, the subdomains are of unequal physical size, and, in general, contain unequal numbers of grid points (see figure). Each processor is assigned a subdomain and is responsible for storing and pushing the particles in this subdomain. Each processor is also responsible for storing the electromagnetic-field quantities for the grid points of its assigned subdomain. As a particle moves to a new subdomain, the particle is passed to the processor asigned that subdomain in this primary decomposition.

The primary decomposition is not generally the optimum for solving the electromagnetic-field equations in parallel. Therefore, the secondary domain decomposition is chosen to make the concurrent field solution efficient and is used only for this and related diagnosis. The specific decomposition depends on which method of solution is used. In general, the most efficient decomposition for the field solution is likely to involve dividing the number of grid cells equally among the processors.

At each time step, prior to solving the field equations, the relevant charges and current densities at the grid points are passed among the processors and redistributed as needed in the secondary decomposition. After the field equations are solved, the electromagnetic-field quantities must be passed among the processors so that they are distributed as needed in the primary decomposition for the particle computation.

This work was done by Paulett C. Liewer of Caltech and Viktor K. Decyk of UCLA for **NASA's Jet Propulsion Laboratory.**
NPO-17737/TN

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Department of Energy

Technology Application

Ames Laboratory

Analyzing Environmental Pollutants

Detecting environmental pollutants requires sensitive and element-selective analytical devices. Ames Laboratory scientists have developed the Helium Afterglow Discharge Detector (HeAD) to meet this need. The HeAD can distinguish between sulfur- and phosphorus-containing pesticides such as malathion and parathion and between chloride-, bromide-, and iodide-containing organic compounds, which may be mutagenic. It stands out as one of only two detectors with the potential to identify every element, except helium, with high sensitivity. The HeAD, winner of a 1985 IR-100 Award, also has the potential for giving online chemical formula information about unknown compounds. This makes it well-suited for quality control during the production of many industrial materials. Applications include the detection of arsenic contaminants during plastics manufacturing and tracking impurities in flue gas. When a sample is injected into the instrument, sample atoms are broken apart upon collision with the helium atoms and molecules. Helium is used because its excited atoms and molecules have higher energy than those of nitrogen and argon. It is thus more efficient in exciting smaller traces of substances. In this process, the helium transfers its energy to the sample atoms. As the sample atoms eventually lose this energy, they emit a colored afterglow that fingerprints their identity. By observing the wavelength pattern of the optical spectra, users of the HeAD can identify all the elements in a compound. HeAD offers several advantages over other instruments on the market. Used in conjunction with a gas chromatograph, it feeds each sample fraction directly into the afterglow at atmospheric pressure, and is faster and more energy-efficient. Because it can detect all elements to the parts-per-billion level, it replaces six to eight detectors that would otherwise be needed to achieve the same range of capabilities. This eliminates the need for costly supplemental attachments.

Literature: G.W. Rice, A.P. D'Silva, and V.A. Fassel, "A New Helium Discharge Afterglow and its Application as a Gas Chromatographic Detector," *Spectrochemica Acta*, Vol. 40B, p. 1573-1584, 1985.

Laboratory Name: Ames Laboratory.

Reference No.: AL-89-01.

Patent Status: U.S. Patent No. 4,586,368. Licensed to CETAC Technologies, Ames, IA.

FOR ADDITIONAL INFORMATION: Williams, D.E., Office of Research and Technology Application, Ames Laboratory, 119 Office and Laboratory, Iowa State University, Ames, Iowa 50011; Telephone: Commercial: (515)294-2635.

Department of Energy

Technology Application

Ames Laboratory

Differentiating Mirror-Image Molecules

An analytical instrument, a Micropol LC detector, developed at the Ames Laboratory differentiates mirror-image forms of a molecule. It is used in conjunction with liquid chromatography. The Micropol detector provides a different way of detecting biologically important compounds, based on their optical activity, or ability to rotate a plane of polarized light. The direction of rotation determines whether a molecule is the left- or right-handed form. The angle of rotation is dependent on the identity of the compound and is proportional to its concentration. The instrument's revolutionary design combines three outstanding capabilities. It can measure 10^{-6} degrees of rotation, which translates to an ability to detect nanogram quantities of a material. This sensitivity is a thousand times greater than that of existing devices. Analyses can also be performed with much smaller sample volumes. This allows the Micropol to accommodate the improvements in liquid chromatography that have led to smaller elution volumes. The Micropol LC requires only .1 or .001 ml of sample which is 50 to 500 times less than that required by other systems that measure optical activity. The third advantage of the Micropol is its rapid response time (1 second) and ability to monitor flow streams, which make it well-suited for analyzing industrial process streams in real time. Its response is predictable, allowing accurate measurements. These features give the Micropol LC the flexibility to perform a wide range of analyses - from determining various forms of sugar to classifying coals to archeological dating of amino acids. The analyses can be performed virtually anywhere - R & D laboratories, clinics, and even industrial production areas. The invention received an R & D 100 Award in 1989.

This instrument contributes to the diagnosis of heart disease; determining drug purity; classifying coals, sugars in urine, and protein conformations; and identifying amino acids for archeological dating.

Literature: D.R. Bobbitt and E.S. Yeung, "Absorption Detection in Microcolumn Liquid Chromatography via Indirect Polarimetry, " *Analytical Chemistry*, Vol. 57, 1985, p. 271.

Laboratory Name: Ames Laboratory.

Reference No.: AL-89-03.

Patent Status: U.S. Patent No. 4,498,774. Licensed to Rudolph Research Company, Fairfield, NJ.

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Department of Energy

Technology Application

Idaho National Engineering Laboratory

High-Temperature Quantitative Dilution Device for Oxides of Nitrogen Measurements via Chemiluminescent Monitors

High-temperature dilution devices are not commercially available. Many conventional analytical instruments could be used if reactive gas mixtures could be quantitatively diluted to non-reactive levels. The dilution device demonstrated at INEL uses a high-temperature capillary to quantitatively dilute hot-reactive gas mixtures of water vapor, nitric oxide, nitrogen dioxide, and ammonia to levels in which the mixture is non-reactive (kinetically frozen) and below the level in which water condenses at ambient conditions. The capillary is calibrated by passing known volume of air through it at a specified temperature (230 degrees C in this case) and measuring the pressure drop vs time. Flow through the capillary is obtained for a wide range of pressures. The flow from the capillary is diluted by a factor of 1,000 to 10,000 by a hot aspirator dilution airstream and cooled to room temperature. The kinetically frozen mixture is passed through a chemiluminescent monitor to measure the nitrogen oxide species under ambient conditions.

The dilution device could be coupled with infrared (IR) and ultraviolet (UV) spectrophotometers, mass spectrometers, gas chromatographs, and other instruments for process- and stack-gas stream analyses.

Laboratory Name: Idaho National Engineering Laboratory.

Reference No.: DOE-INEL-055.

Patent Status: Patent pending. Available for licensing.

FOR ADDITIONAL INFORMATION: Campbell, R.R., Executive Vice President, Westinghouse Idaho Nuclear Co., Inc., P.O. Box 4000, Idaho Falls, ID 83403; Telephone: FTS: 583-0997; Commercial: (208)526-0997.

NASA Tech Brief
National Aeronautics and Space Administration
Goddard Space Flight Center, Greenbelt, Maryland

Licensing Opportunity

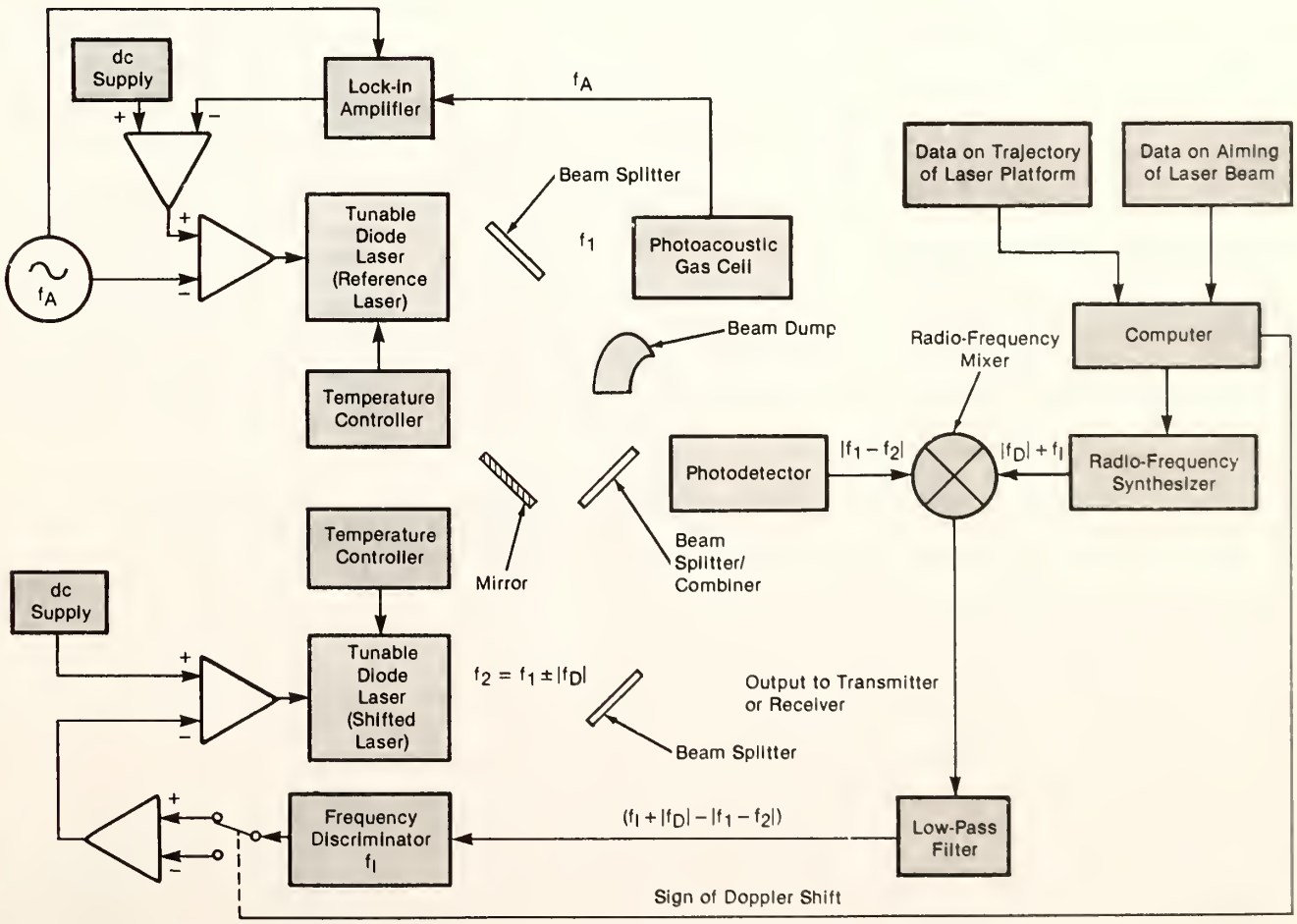
Compensating for Doppler Shift in Laser Instrumentation

The frequency of a tunable diode laser is adjusted to oppose the shift.

An electronic tuning system continually adjusts the frequency of a tunable diode laser to compensate for the Doppler shift caused by the motion of a transmitter or receiver that contains the laser. The Doppler-shift-compensating system is intended primarily for use in the transmitter or receiver of a laser remote-sensing or communication system to keep the frequency of the received signal within the frequency range of a narrow-band-pass filter. By use of the narrow-band filter (instead of the wide-band filter that would be required in the absence of Doppler compensation), the signal-to-noise ratio of the laser system can be increased. Thus, a less-powerful transmitter might be usable.

The system (see figure) includes two current-modulated tunable diode lasers, the first of which provides an unshifted reference frequency f_1, and the second of which puts out the Doppler-compensated signal at frequency f_2. The frequency of the reference laser is dithered at an acoustic frequency f_A about the steady or slowly varying value f_1. The dither is detected in a photoacoustic gas cell, which is part of a first feedback loop that adjusts the direct current supplied to the laser to keep f_1 at the frequency of an atomic- or molecular-energy-level transition of the gas in the cell.

Parts of the outputs of both tunable diode lasers are sent to a photodetector, which acts as a mixer in putting out a signal that contains the beat frequency $|f_1 - f_2|$. At the same time, a computer calculates the expected Doppler shift f_D from data on the trajectory of the laser platform and the direction of aim of the laser beam. The computer commands a radio-frequency synthesizer to put out a signal at a frequency of $|f_D| + f_I$, where f_I is an intermediate radio frequency. The $|f_1 - f_2|$ and $|f_D| + f_I$ signals are fed to a radio-frequency mixer, the output of which is low-pass filtered to yield the component that has the frequency $f_I + |f_D| - |f_1 - f_2|$. This signal is fed to a frequency discriminator tuned to f_I, and the output of the discriminator is fed to the inverting or noninverting input of a differential amplifier, depending on the arithmetical



The **Electronic Tuning System** continually strives to maintain the output frequency f_2 at a value shifted above or below the reference frequency f_1 by an amount that compensates for the computed Doppler shift f_D.

sign of the computed Doppler shift. The output of the differential amplifier is fed to another differential amplifier, which adjusts the dc supply of the shifted laser. This completes a second feedback loop that continually strives to keep the output frequency of the shifted laser at $f_2 = f_1 + f_D$.

This work was done by Geary K. Schwemmer of **Goddard Space Flight Center**.

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Goddard Space Flight Center. Refer to GSC-13194/TN.

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NASA Tech Brief
National Aeronautics and Space Administration
Lyndon B. Johnson Space Center, Houston, Texas

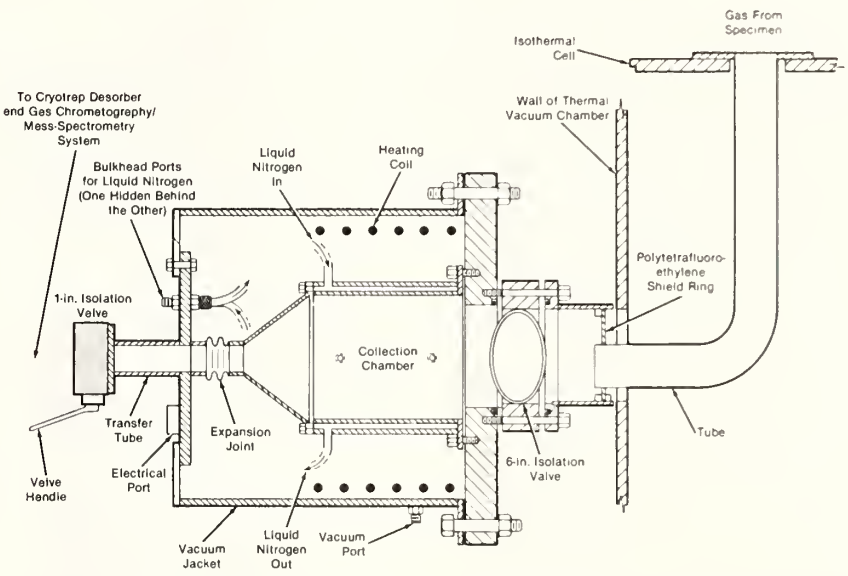
Concentrating Gaseous Contaminants for Monitoring

Amounts of outgassed substances can be analyzed as functions of time and temperature.

An apparatus concentrates contaminants outgassing from specimens in a vacuum and passes the concentrated contaminants to a gas-chromatography/mass-spectrometry system for analysis. The apparatus thus enables measurements of the fluxes of various contaminants as functions of time and/or temperature. The apparatus makes it possible to determine whether candidate materials for use in vacuum environments — for example, those in equipment used to manufacture semiconductors — will generate harmful substances.

The apparatus (see figure) uses thermal adsorption and desorption to collect and concentrate the outgassed substances. The specimen to be evaluated is placed in an isothermal cell in a thermal vacuum chamber where it is maintained at a preselected constant temperature. A tube carries outgassed substances from the specimen to a collection chamber. The hollow wall of the collection chamber is cooled by liquid nitrogen so that it will adsorb the outgassed products on its surface.

After a preset interval, the inlet isolation valve is closed, sealing the collection chamber from the specimen. The wall of the collection chamber is then heated to drive the adsorbed substances from its surface. The outlet isolation valve is opened to let the substances flow to a gas chromatograph and mass spectrometer for analysis.



The **Cold Wall of the Collection Chamber** adsorbs gases from a specimen in an isothermal cell. When the wall is subsequently heated, the plate desorbs the gases so that they can be analyzed. The collection chamber is maintained at a low pressure throughout the adsorption and desorption process.

The measurements are repeated at various temperatures of the specimen and various collection times. The data thus provide time and temperature plots of outgassed species and concentrations.

This work was done by William C. Mahone of Lockheed Engineering & Management Services Co., Inc., for **Johnson Space Center**. *No further documentation is available.* *MSC-21424/TN*

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NASA Tech Brief
National Aeronautics and Space Administration
Lyndon B. Johnson Space Center, Houston, Texas

Licensing Opportunity

High-Pressure Promoted-Combustion Chamber

An improved version of an existing chamber would burn specimens in oxygen.

A proposed combustion-testing chamber would burn specimens of materials in a fully contained, high-pressure oxygen atmosphere. The chamber would be an improved version of one now used for evaluation of materials for use in such high-pressure oxygen equipment as regulators, valves, turbopumps, medical equipment, and deep-sea-diving apparatus, for example.

The chamber (see figure) would feature a quick-closure seal to facilitate the insertion and removal of specimens. Specimens would be mounted in a holder introduced through an opening at the bottom of the chamber. Each end of the chamber would be sealed by a plate, O-ring, and threaded retaining ring.

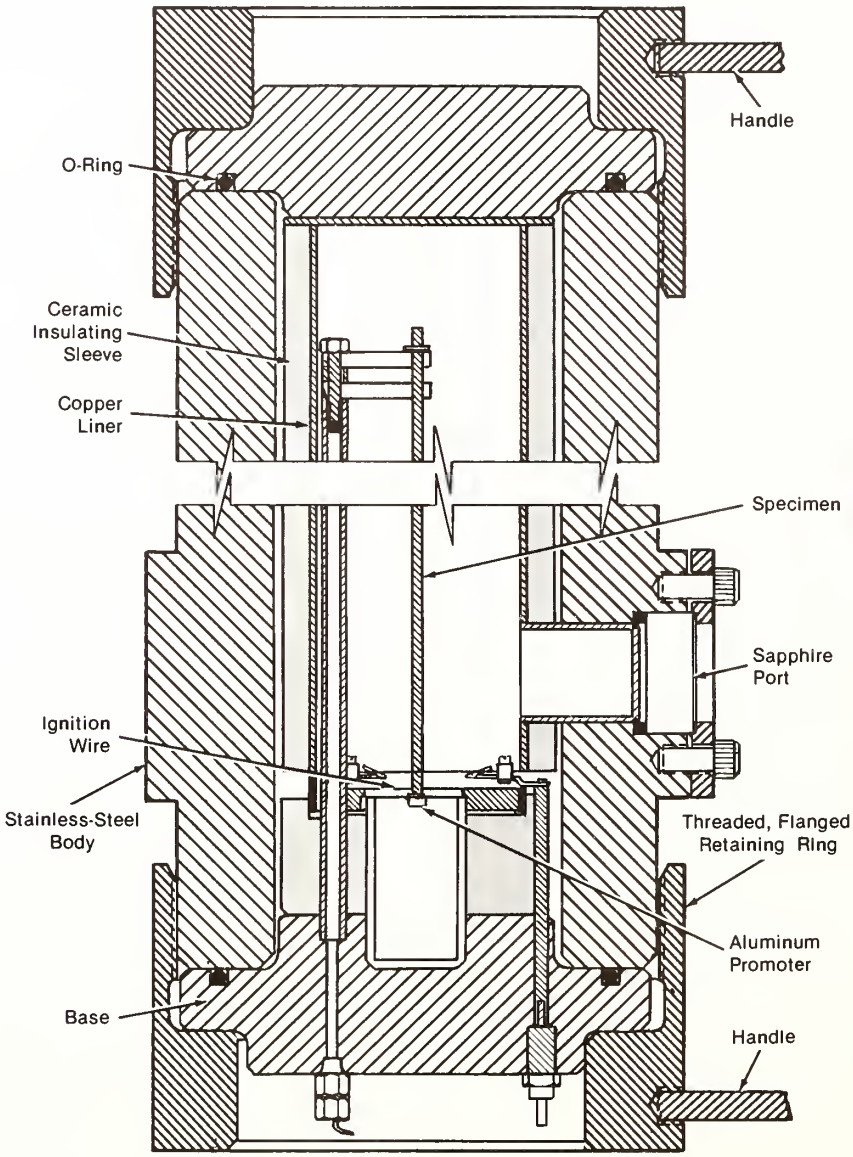
The holder would keep the specimens precisely vertical and position them repeatedly in the same place. The chamber would be able to withstand internal pressures up to 10,000 lb/in.^{2} (69 MPa). The relatively large internal volume of 760 in.^{3} (12.5 L) would provide ample oxygen for combustion.

The stainless-steel body of the chamber would contain four sapphire ports so that tests can be observed with a two-color optical pyrometer, video camera, and x-ray camera. Thermopiles would monitor the propagation of the flame along each specimen. The igniter would comprise an electrically-heated aluminum/palladium wire wrapped around an aluminum promoter (i.e., fuze) at the bottom of the specimen. Combustion could be directed either upward or downward. A copper sleeve and ceramic insulation would protect the inner wall of the chamber from burning debris.

Tests could be conducted in static or flowing oxygen. The oxygen inlet and outlet would be far enough above the burning specimen that there would be little danger of entrainment of burning fragments in the oxygen flowing out.

This work was done by Michelle A. Rucker and Joel M. Stoltzfus of **Johnson Space Center.**

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Johnson Space Center. Refer to MSC-21470/TN.



The **Test Operator Would Use Handles** on threaded retaining rings to attach or remove the top or bottom plates that would seal the combustion chamber.

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Transportation & Components

0104 Comparison of Calculations of Viscous Transonic Flow—Results of a variety of numerical simulations are compiled in a report for easy comparison.

0105 Measurement of Water Sprays Generated by Airplane Tires—Water sprays produced by tires on wet runways are simulated and analyzed.

0106 Predicting Unsteady Aeroelastic Behavior—The equations for the motion of the wing and the flow field are solved iteratively and simultaneously.

0107 Simulation of Three-Dimensional Supersonic Flows—Complicated flows can now be computed with fair accuracy.

Other Items of Interest

0048 Helmet-Mounted Visual Display for Flight Simulation—Optical fibers transmit wide-angle images in response to motions of the head. (Licensing Opportunity)

NASA Tech Brief
National Aeronautics and Space Administration

Comparison of Calculations of Viscous Transonic Flow

Results of a variety of numerical simulations are compiled in a report for easy comparison.

A report presents a compendium of results of numerical simulations of viscous transonic flows about airfoils. The results, which were reported at the 1987 Viscous Transonic Airfoil Workshop, appear in the report in narrative, tabular, and graphical form to facilitate comparisons with each other and with measured data.

Fifteen working groups are represented by 23 sets of numerical results. These airfoils were used in this study and are given by:

- The classical NACA 0012 airfoil,
- The RAE 2822 supercritical airfoil, and
- The recently-developed Jones airfoil.

The test cases range from attached subcritical flows to transonic flows with separations induced by both shocks and angles of attack. The working groups used methods ranging from momentum-integral boundary-layer techniques coupled with transonic potential inviscid codes to full Navier-Stokes techniques.

The report concludes that, for calculations of attached flows about airfoils, numerical methods have reached a high level of development. Most methods can predict lift to an accuracy within ±3 percent and drag to within ±5 percent. Other computed flow-field data — such as velocity boundary-layer profiles and skin-friction distributions — are in good agreement with each other and with experiments.

However, for calculations of separated flows about airfoils, numerical methods are not developed as well. This is largely because the mathematical modeling of turbulence in regions of separated flow is not accurate. Recent progress suggests hope for the future, nevertheless.

The report notes that many errors in computer programs are solely numerical in nature. Comparisons of solutions with each other are valuable because they enable the identification of such errors. The most important numerical errors are caused by inappropriate clustering and refinement of computational grids. Further studies of the refinement of grids could help to eliminate these errors.

This work was done by Terry L. Holst of **Ames Research Center.**" *Viscous Transonic Airfoil Workshop Compendium of Results.*" *ARC-12192/TN*

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NASA Tech Brief
National Aeronautics and Space Administration
Langley Research Center, Hampton, Virginia

Measurement of Water Sprays Generated by Airplane Tires

Water sprays produced by tires on wet runways are simulated and analyzed.

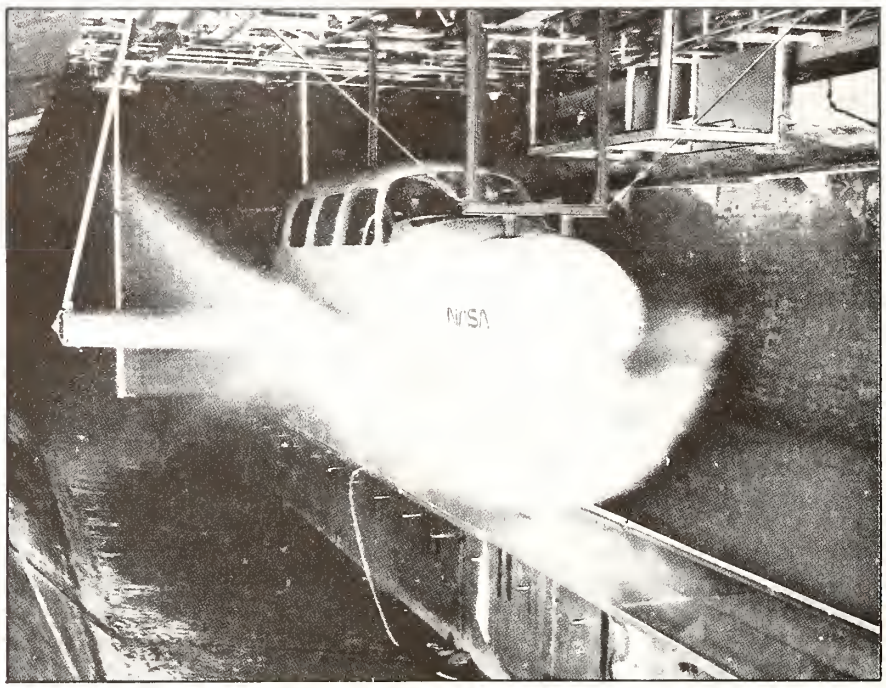
All aircraft designed to take off and land on a conventional runway must be able to operate when the runway is wet. Sprays thrown up by the aircraft tires into the intakes of engines pose a danger: if sufficient water is ingested, a jet engine can undergo compressor stalls or even flameout, either of which can be especially dangerous if it occurs on the takeoff roll near rotation speed. Numerous studies to determine whether aircraft are susceptible to the ingestion of water spray have typically been carried out after the aircraft were built. It is desirable to have a technique that makes it possible to configure an aircraft and its engines in a geometry that eliminates the potential for the ingestion of spray.

An experimental investigation was conducted at the NASA Langley Research Center to measure the rate of flow and the trajectory of water spray generated by a tire operating on a flooded runway. Tests were conducted in the Hydrodynamics Research Facility, which contains a 2,900-ft (600-m)-long enclosed water tank approximately 12 ft (3.7 m) deep and 24 ft (7.3 m) wide. The tests made use of a partial airframe and a nose wheel (see figure).

To capture the water, two different collectors were built. The first collector consisted of an 8-by-8 array of tubes spaced at intervals of 3 in. (7.6 cm) between axes. Later in the test program, a larger water collector was fabricated with a 22-by-22 array of tubes with the same spacing as that of the previous collector. Each tube in the array was a clear plastic cylinder with a 1.625-in. (41.28-mm) inside diameter and with a removable rubber stopper placed in the aft end.

A collector was mounted on the carriage behind and to the right of the test tire to sample the water spray generated by the nose tire as it ran through the flooded runway. The collector was slightly tilted with the aft end low, so that the collected water remained in the tubes when the carriage decelerated. After the test, the volume of water collected in each tube was measured to obtain an indication of the rate of flow at that position.

A video camera showed whether a complete sampling of spray was obtained. Additional data were obtained by use of high-speed movie film in cameras, mounted both aboard the moving carriage and along the side of the runway, aimed at the test wheel. The movies helped to define the trajectory of the water spray relative to the ground.



The **Water Spray Generated by a Tire on a Wet Runway** was simulated by use of part of an airframe with a nosewheel in a test facility.

The water collector was positioned for each test run at a selected location to the side of the centerline of the nose wheel. The water-collector-mounting hardware allowed the collector to be moved in three directions. Each test run was begun by accelerating the carriage to the desired speed. The nose tire ran up an entrance ramp to load the tire, traversed the flooded runway, and then ran down an exit ramp. Then the carriage was slowed to a stop. The effects of forward speed, load on the tire, and depth of water on water-spray patterns were evaluated.

Water ejected from the side of the tire footprint was found to have the most significant potential for ingestion into engine inlets. Forward speed increased rates of flow and moved the spray pattern inboard. Increased loads on tires caused the spray to become less dense. Near the tire, increased depths of water caused rates of flow to increase. Tests using a fuselage and partial wing along with the nose gear showed that for certain configurations, the aerodynamics of the wing can cause a concentration of spray above the wing. Tests showed virtually identical spray-pattern and flow-rate behavior when comparing tires of bias-ply versus radial-ply construction. The methodology and the results of the tests have potential for application to both aircraft and automotive industries, with particular application to manufacturers of tires.

This work was done by Robert H. Daugherty and Sandy M. Stubbs of **Langley Research Center.** *Further information may be found in NASA TP-2718 [N88-24458], Price Code: A06 "Measurements of Flow Rate and Trajectory of Aircraft Tire-Generated Water Spray."*

Copies may be purchased from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700. *LAR-14030/TN*

NASA Tech Brief
National Aeronautics and Space Administration
Langley Research Center, Hampton, Virginia

Predicting Unsteady Aeroelastic Behavior

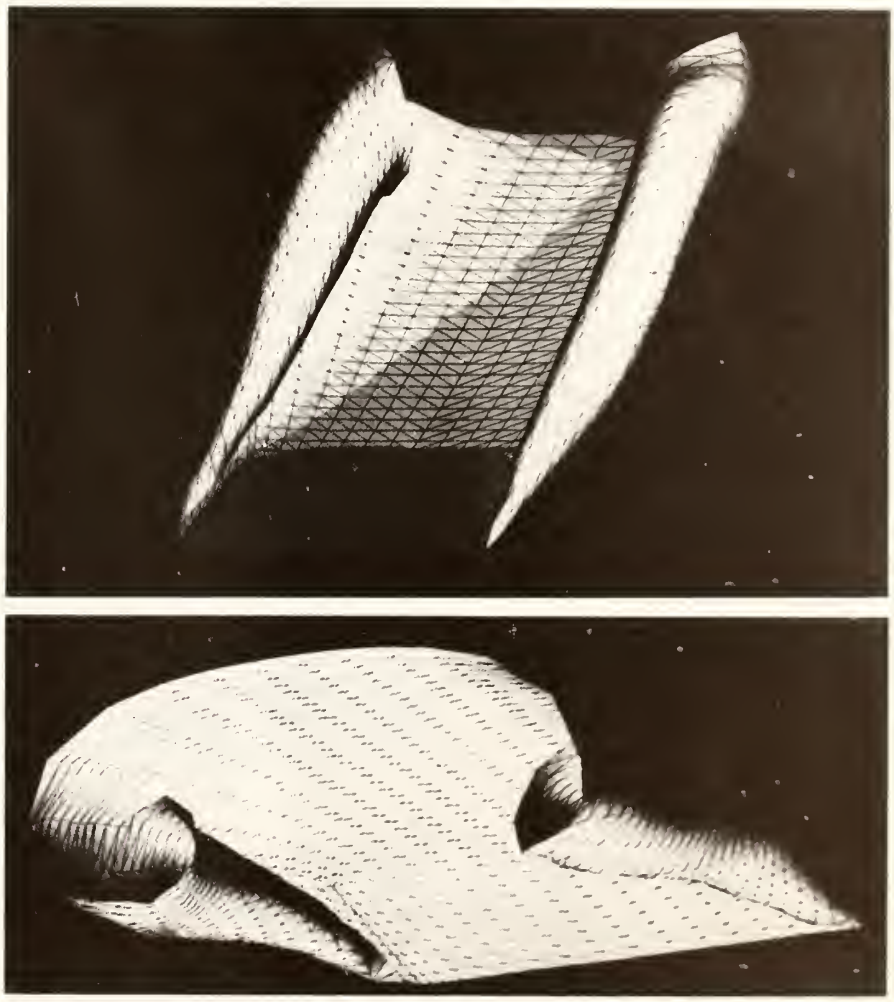
The equations for the motion of the wing and the flow field are solved iteratively and simultaneously.

A new method for predicting subsonic flutter, static deflections, and aeroelastic divergence has been developed. The unsteady aerodynamic loads are determined by the unsteady-vortex-lattice method. The method accounts for the aspect ratio and the angle of attack. The angle of attack is limited only by the occurrence of stall or vortex bursting near the wing.

The method simultaneously and interactively integrates the equations of motion of the structure and the flow field. However, a complication arises in this approach: the aerodynamic loads cannot be predicted unless the motion of the wing is known, and the motion cannot be pedicted unless the aerodynamic loads are known. Hence, an iterative scheme, based on the predictor-corrector method, provides the motion of the wing and the flow field simultaneously and interactively. The solution can predict aeroelastic divergence, flutter boundaries, transient motion, and deformations due to steady loads.

The differential equations of motion are developed for bending and torsion about a static angle of attack. The deflections (both rotation and translation) are expanded in terms of the free-vibration modes. The time-dependent coefficients in these expansions are then treated as generalized coordinates. The static problem, which is nonlinear in the aerodynamic loads, can be solved by iteration. The scheme provides the deflection due to static aerodynamic loads and weight; that is, the equilibrium solution.

The time-dependent displacements from the position are obtained in the analysis of flutter. The analysis of the static problem begins with the specification of a nominal angle of attack and the calculation of the corresponding distributed loads. Then these loads are used to calculate the bending and torsional deflections. At this point, the wing has a new shape, but the loads still correspond to the old shape. New loads, corresponding to the new shape, are obtained next; then another new shape is calculated. The procedure is repeated until either the shape and loads converge or aeroelastic divergence occurs. The method graphically animates the flow field and wing motion, as illustrated in the figure.



The **Wing and Flow Field Are Graphically Animated** by use of this modeling technique.

For the dynamic problem, the integration process is based upon Hamming's predictor-corrector technique. A typical time step begins when the current loads and those at three previous time steps are used to predict the state variables (generalized coordinates and their derivatives) at the next time step. Then the new state variables are used to predict the loads at the next time step. These loads are then used to improve the predicted state variables, which in turn are used to improve the predicted loads. The iteration continues until convergence occurs. Then the procedure marches ahead to the next time step. When flutter does not occur, the dynamic solution converges to the static solution.

This technique was used to simulate flutter of a rigid wing mounted on an elastic support limited to two degrees of freedom (plunge and pitch about the elastic axis). The results simultaneously and interactively predict the motion of the structure and the motion of the fluid in the time domain. Because the wake is generated as part of the solution, the history of the motion is included in the analysis.

The method can be used to predict the transient responses to initial disturbances. (Indeed, flutter boundaries are obtained by observing the character, growing or decaying, of such responses.) It can also be used to predict steady-state static and oscillatory responses. In addition to aerospace applications, this technique has potential

for research in such unsteady structural/flow interactions as those in windmills, turbines, and compressors.

This work was done by Thomas W. Strganac of **Langley Research Center** *and Dean T. Mook of Virginia Polytechnic Institute and State University.*
LAR-14130/TN

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
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NASA Tech Brief
National Aeronautics and Space Administration

Simulation of Three-Dimensional Supersonic Flows

Complicated flows can now be computed with fair accuracy.

A report describes simulations of steady, three-dimensional, viscous, supersonic flows by the NASA Ames Parabolized Navier-Stokes computer code. When executed on a suitable computer, this code can simulate flows about bodies of practical complexity — even whole aircraft.

The computer code is based on the assumption that the flow is supersonic in the streamwise direction and that the subsonic flow in the viscous sublayer is always positive in the streamwise direction. Flows with large streamwise separation and reversals of flow are excluded from treatment under these assumptions. However, crossflow separations are permitted.

Under these assumptions, the Navier-Stokes equations become parabolic in the streamwise direction, enabling a marching-solution procedure, which is computationally desirable and efficient. The boundary conditions are the usual viscous no-slip at the wall, and a characteristic procedure is used to fit the bow shock wave, which is the outermost boundary. Because the equations are cast in conservation-law form, all discontinuities within the flow domain are predicted accurately. Because of the possible complex nature of the configuration at each axial location as one proceeds along the body, an elliptic grid generator is employed to discretize the domain of the flow.

The code has been used to simulate flows about several different solid bodies, including a blunt cone, a biconic vehicle with a spherical nose, the Space Shuttle orbiter, and a generic fighter airplane. Laminar and turbulent flows, various angles of attack, and various speeds from mach 2 to mach 14 have been considered. For the most part, the computed flows agree fairly well with measured flows. The results show that the code predicts flows in regions of canopies, wings, and canards in addition to the simple symmetric configurations ordinarily used to demonstrate computational techniques. The code also simulates interactions between aerodynamic surfaces; for example, the vortex interaction between canards and wings.

This work was done by Denny S. Chaussee of **Ames Research Center**. *Further information may be found in NASA TM-100082 [N88-21421], Price Code: A03 "High-Speed Flow Calculations Past 3-D Configurations Based on the Reynolds Averaged Navier-Stokes Equations."*

Copies may be purchased from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700. *ARC-12235/TN*

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